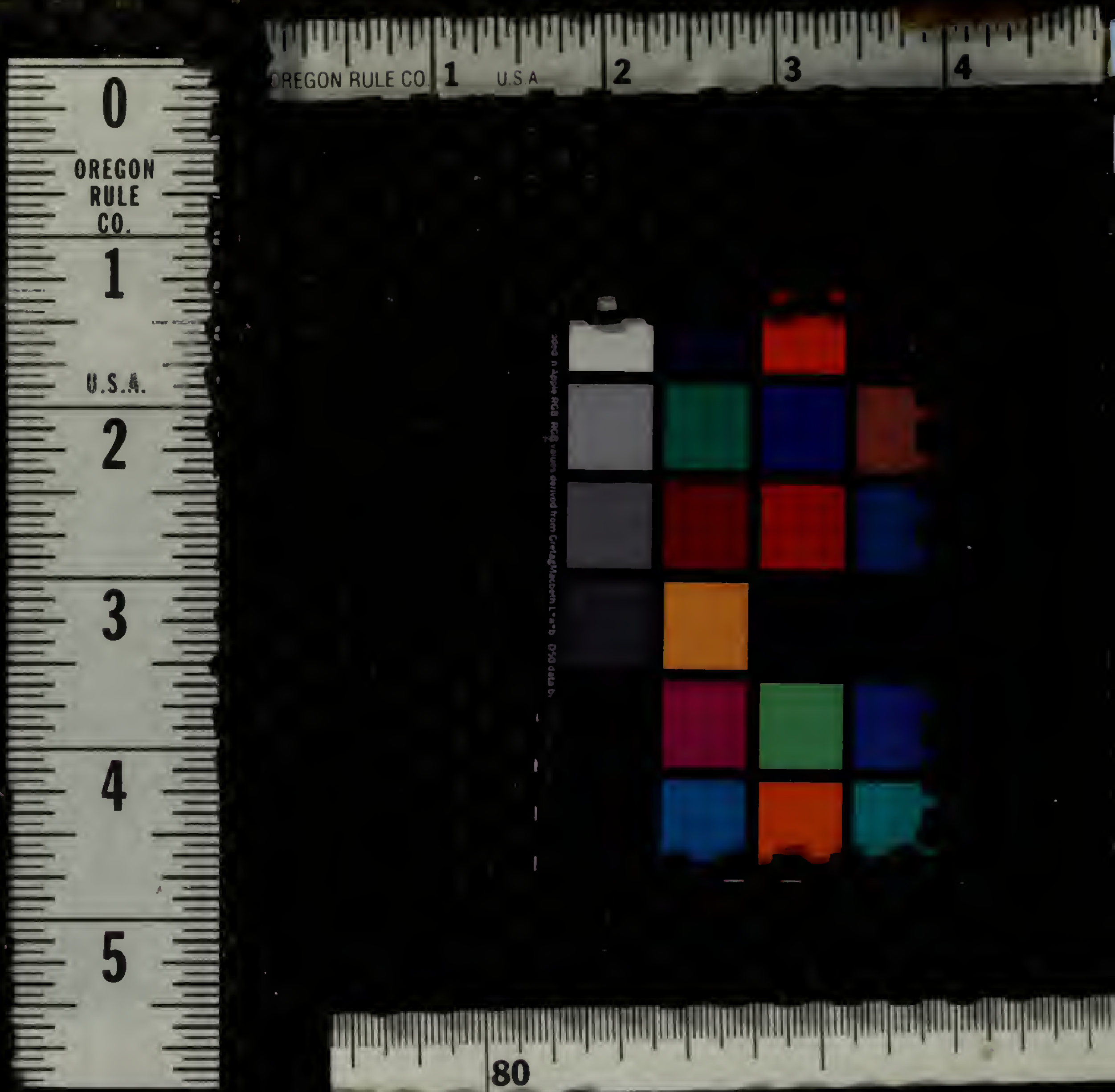

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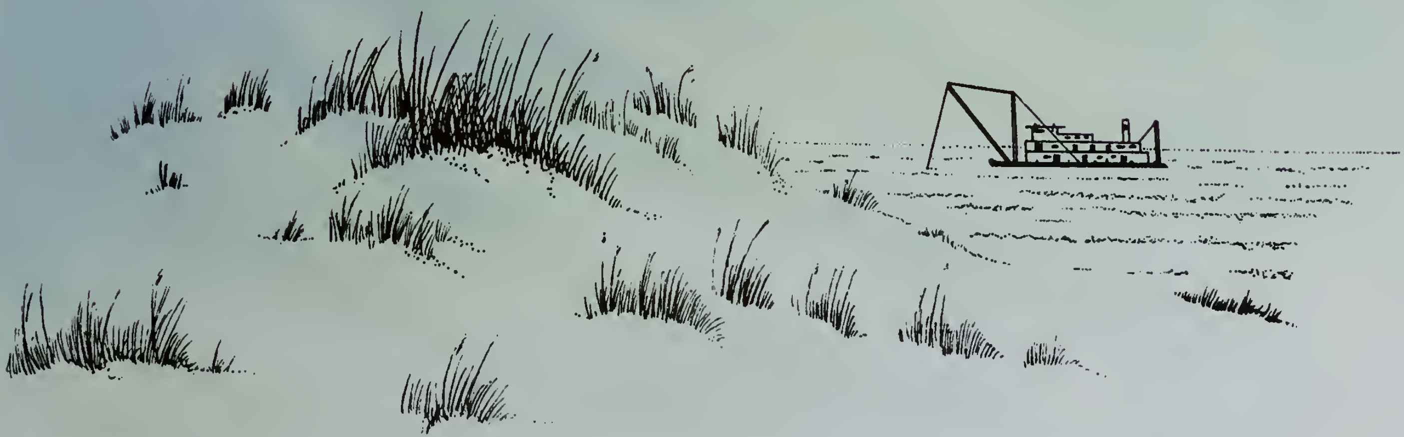
Effects of Inlet Maintenance and Recommended Action

by C.W. Shabica, S.V. Cofer-Shabica, S.L. Boom and D.E. Anderson



INLETS OF THE SOUTHEAST REGION NATIONAL SEASHORE UNITS: EFFECTS OF INLET MAINTENANCE AND RECOMMENDED ACTION

U.S. Department of the Interior National Park Service

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This document has been prepared to fulfill the following objectives: (a) to provide an historic review and evaluation of the effects of inlet maintenance on adjacent Southeast Region National Park units, and (b) to develop recommendations for remedial measures as part of the ongoing National Park Service (NPS) Southeast Regional Office (SERO) coastal research program.

Coastal units of the Department of the Interior included in the study:

Cape Hatteras National Seashore

Cape Lookout National Seashore

Cumberland Island National Seashore

Castillo de San Marcos and Fort Matanzas National Monuments

Canaveral National Seashore and Merritt Island National Wildlife Refuge

Gulf Islands National Seashore

After evaluation of available data and reports we draw the following conclusions: (a) comprehensive strategies for resource monitoring and management should be developed for each NPS unit using input from a multi-disciplinary team of experts from affected agencies including NPS, U.S. Army Corps of Engineers (COE), state transportation departments and others as appropriate. A successful model for this approach is the Kings Bay Project, Cumberland Island National Seashore (NS). (b) resource management databases must be established on both a regional and a park-specific basis to effectively inventory, monitor change and manage resources, (c) environmental and economic impacts of non-structural versus structural options for inlet channel maintenance should be carefully reviewed by the management team before new solutions are proposed, (d) sand management methods must be implemented at modified inlets in a manner to minimize negative impacts on coastal ecosystems and sand resources, (e) ship channels must be relocated away from migrating barrier islands, and (f) alternative use studies should be authorized for extensively modified areas.

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1.0 Report Introduction

An extraordinary and challenging set of conditions confront superintendents, resource managers, and other administrators and specialists of coastal National Park units located in the southeastern region of the United States. Natural processes and man-made modifications to inlets on these evolving coasts often severely and negatively effect seashore features and unit boundaries. These impacts are of particular concern for the units that include fragile and highly dynamic coastal barrier islands. Distinguishing between natural effects of inlets on coastal processes, and man-induced effects is often difficult especially as complete resource inventories of the units are generally not available.

Until recently, the computer hardware and software needed to handle resource inventory and management tasks were not readily available, affordable, or practically adaptable to meet park administrative and management requirements. Further, the organization and input of historic data continue to be difficult to standardize. Although hundreds of coastal and inlet surveys have been completed since much of the southeastern area came under Federal control in the early 1800s, few studies produced standards and practices that can be applied to the management of coastal environments. Despite concentrated efforts in more recent decades by many institutions and professionals, the condition of constant coastal evolution has made accurate base-line positioning and measurement difficult to obtain. More than 700 sources supplied data to the Coastal Erosion Information System (CEIS) that was set up by the Coastal Research Group of the University of Virginia in 1982. Yet, after nearly 10 years of working with the data, CEIS founder Robert Dolan reported to the National Conference on Beach Preservation Technology (Dolan et al., 1991) that the data had limited use because "coastal scientists and engineers, unlike meteorologists and oceanographers, have not developed a standardized methodology for collecting and analyzing changes in the shorelines." Due to recent advances in resource management database (RMDB) information management technologies, this situation is now being improved. The necessary tools are now available and include among others, computerized RMDB, inventory and monitoring (I&M) programs, geographic information systems (GIS), global positioning systems (GPS), satellite surface mapping and advanced aerial photogrammetry and remote sensing.

For more than two centuries, the primary interest of government agencies in coastal engineering has been to keep ship channels for commercial and military vessels open and aligned for navigation, and to arrest the movement of sediments back into the channels through dredging and the construction of jetties, groins, and breakwaters. An unintended result of these modifications in the southeastern region where large quantities of sand typically move along shore in the littoral drift system, was a sand-deficit and consequent acceleration in shore erosion. In South Carolina and Georgia where tidal processes are important, jetties have caused the displacement of tidal deltas offshore also resulting in accelerated shore erosion.

Over the years, millions of cubic meters of sand and sediment have been diverted offshore or dredged out of both "modified" and "natural" inlets and passes in the southeastern region of the United States. These materials have often been transported beyond

the surf zone in waters too deep for waves to return the sand to the littoral system. Results include deeper and steeper nearshore bottom profiles, and narrowed beaches that would otherwise have been primary lines of coastal and barrier island defense against storm waves. Robert Dean (1988) estimated "that 80% of the erosion along Florida's east coast is due to poor sand management practices which continue today, albeit to a lesser degree."

In 1993, as a matter of practice by the COE, sediments dredged from shore or nearshore locations are generally kept within the littoral drift system (Susan Reese, Mobile District, USACE MD, personal communication, 1993). This should be continued. In order to minimize the impact of inlet maintenance, net volumes of dredged or impounded material must be returned to the system in appropriate locations and rates.

As noted above, one conclusion is a strong recommendation that each of the parks should ensure that as much material as possible that is removed from the longshore, sediment-transfer system is replaced directly back into the system and not in offshore locations where only unusually severe wave action can recover it. Further, channel relocation is recommended for Gulf Islands National Seashore areas where fragile wildlife refuges are being eliminated by dredging processes as the refuge islands themselves migrate into the maintained channels. Finally, we recommend a study of management strategies be conducted for areas that are maintained through engineered structures or procedures, such as the newly constructed lands adjacent to the terminal groins at Cape Hatteras National Seashore.

2.0 Descriptive Summary of Seashores & Other Units

Six national seashores, two national monuments, and two national wildlife refuges in the Southeast Region of the National Park Service have been, and continue to be, affected by channel dredging and inlet stabilization projects that are conducted in coastal inlets within and adjacent to park boundaries (Fig. 1). A brief description of these units, inlet stabilization and maintenance efforts, and erosional effects on unit coastlines are provided herein. Assateague NS (NPS Mid-Atlantic Region) is discussed in a separate report.

The Cape Hatteras NS, located on the "Outer Banks" of North Carolina, is the most northern of the units and comprises three highly mobile and eroding barrier islands: Bodie Island, Hatteras Island which contains Pea Island National Wildlife Refuge, and Ocracoke Island. The seashore is also the location of three geomorphologically "active" inlets. Oregon Inlet is located between Bodie Island and Hatteras Island, and Hatteras Inlet is located between Hatteras and Ocracoke Islands. Ocracoke Inlet lies at the southwestern boundary between Cape Hatteras NS and Cape Lookout NS.

Continuing southwest along the Outer Banks past Ocracoke Inlet, three barrier islands make up the primitive wilderness areas of Cape Lookout NS. These include Core Banks (two islands) and Shackleford Banks. Three active inlets, in addition to Ocracoke Inlet, separate the islands in this chain and are New Drum, Barden and Beaufort Inlets.

Both Cape Hatteras and Cape Lookout National Seashores shelter a large part of the North Carolina coastline that would otherwise be directly exposed to North Atlantic storms.

Fig. 1. Southeast Region National Park Service Coastal Units.

Large volumes of sediment are transported along shore and into inlets along this high wave energy and low tide range coast. Erosion is a dominant process caused by storm waves and currents aggravated in various degrees by channel stabilization and dredging at Oregon Inlet in the Cape Hatteras NS, and at Barden and Beaufort Inlets in the Cape Lookout NS.

Oregon Inlet is the proposed site for highly controversial channel-alignment jetties. Management issues include timing and material quantities of channel dredging, locations for placement of dredged material, and the advisability of jetty construction versus intensified dredging activities. At Barden Inlet, entrance channel migration has caused accelerated erosion on Core Banks near Cape Lookout Lighthouse. Dredging has affected the ebb tidal delta at Beaufort Inlet potentially affecting Shackleford Banks, Cape Lookout NS.

South of the Outer Banks, the coasts of South Carolina and Georgia are relics of tidal shoaling typified by Cumberland Island NS in the Georgia Embayment, where the combination of high tides and low wave energy have allowed more inlets to form and be maintained by tidal currents. The seashore protects the entrance to St. Marys River at the south end of the island. A well-developed ebb tidal delta lobe extends seaward of the inlet

and has been extensively modified by entrance jetties built in the late 19th century. In addition to problems caused by dredging, the collapse of the ebb delta may cause extensive and long-term problems to this region. Understanding the dynamics and evolution of the ebb delta system is critical to the long term management of St. Marys Inlet and Cumberland Island NS.

Castillo de San Marcos, the historic Spanish fort dating back to the mid-sixteenth century is located on the northern coast of Florida between the City of St. Augustine and seaward barrier islands. This National Monument and Fort Matanzas, located on Rattlesnake Island, guarded the entrances to the ancient City of St. Augustine and the Matanzas River (respectively) 22 km (14 mi) to the south. The effects of erosion from channel stabilization and dredging upon both park units differ considerably. Castillo de San Marcos has experienced subtle change, but the changes at Fort Matanzas have been dramatic. The land at Fort Matanzas NS has grown from 0.4 hectares (1 acre) to 121 hectares (298 acres) as a result of Intracoastal Waterway maintenance and accretion at Matanzas Inlet. Although inlet modifications and prior dredging operations at St. Augustine Inlet have caused a deficit in the littoral drift system, there is no evidence that this has had a negative impact as far downdrift as Matanzas Inlet. Erosion on the south shoulder of Matanzas Inlet may require further bridge abutment armoring in the future however.

Canaveral NS and Merritt Island National Wildlife Refuge are located approximately 104 km (65 mi) further South from St. Augustine. Significant erosion has occurred on beaches adjacent (updrift) to these park units. This erosion may be exacerbated by channel stabilization and dredging in the Ponce De Leon inlet located 16 km north of the seashore.

Biscayne National Park was not included in this study and report because the stable, shallow, natural carbonate inlets are protected by an extensive, offshore coral reef system and have required no modification or dredging.

Along the Florida pan-handle and the Mississippi coasts shorelines are two groups of islands that comprise the Gulf Island NS wilderness areas that are the final focus in this report. The Florida section of Gulf Islands includes Santa Rosa Island and Perdido Key, separated by Pensacola Pass, a highly active and dredged inlet. The Mississippi section of Gulf Islands includes four particularly fragile and rapidly migrating islands: Petit Bois, Horn, East Ship, and West Ship Islands. Petit Bois Island is steadily being eliminated by dredging of Pascagoula Ship channel that is located directly adjacent to the downdrift boundaries at the western end of this island.

3.0 Seashore Unit Inlet-Effect Summary

The inlet-effect summary table presented herein itemizes and contrasts types of inlets and inlet dynamics, inlet modifications, channel dredging, and effects of modifications on park unit properties. Mitigation efforts (defined as any actions that minimize inlet impacts) and specific recommendations to further mitigate the problems caused by inlet maintenance complete this section. These data, conditions, and recommendations are discussed in detail within the historic review and inlet-effect evaluations of each park unit.

Note: In all cases develop a Resource Management Data Base (RMDB). Use GIS to store and access coastline and bathymetric data. Survey impacted and control areas to determine relative impact of inlet modification versus other impacts. Digitize key features on aerial photographs including shorelines, dune and vegetation lines.

CAPE HATTERAS NATIONAL SEASHORE

BODIE ISLAND (NPS) Updrift barrier island adjacent to Oregon Inlet

Dynamics: Storm overwash, 97 km of shoreline north of Oregon Inlet receding 1.4 m/y

Littoral Drift: 500,000 m^3/y to 1,000,000 m^3/y net to south

Structures: Bonner Bridge, minimal impact. Proposed jetty will stabilize dynamic south end of Bodie Island and cause beach accretion along Atlantic Ocean side of island.

OREGON INLET Modified and maintained inlet

Dynamics: Highly dynamic, rapidly shoaling, storm and flood-tide dominated sedimentation. Inlet migrating landward 5 m/y and south 23 m/y

Structures: Jetties approved, estimated cost $87,000,000 to construct and $6,250,000 per year maintenance

Dredging: 688,000 m^3/y to 765,000 m^3/y from ocean bar channel and inlet channels. In future, adverse weather conditions may require the occasional use of hopper dredges. Dredging is likely to continue at this level as a dredge-only alternative to jetty construction, or 406,000 m^3/y with jetties

Effects of Modifications: In past, erosion on Bodie and Hatteras Islands was exacerbated by removing dredged sediments from the system. Terminal groin has stabilized the northern 1.6 km of Pea Island

Mitigation Efforts: All 1992 dredged sediments were placed on Pea Island; to be continued

Recommendations: Coordinate monitoring efforts (Modeled on the Kings Bay project) with input from experts representing the NPS, COE and NCDOT

Place dredged sediments on beach or in nearshore locations of Bodie and Hatteras (Pea) Islands to be determined by beach and bathymetric monitoring program

Study alternative uses for stabilized areas near inlet

HATTERAS ISLAND (NPS) Barrier island. Northern end next to Oregon Inlet is called "Pea Island"

Dynamics: Storm overwash, average shoreline recession of 2.6 m/y (northern 21 km of island)

Littoral Drift: 500,000 m^3/y to 1,000,000 m^3/y net to south

Structures: Terminal groin has stabilized Pea Island. Proposed jetties will cause sand fillet accretion adjacent to south jetty and cause downdrift sediment deficit. Model studies indicate that summer season dredging and beach placement on the downdrift barrier island (typically 406,000 m^3/y deposited on Hatteras Island) will mitigate erosional effects of the jetties

OCRACOKE INLET Natural inlet

Structures: None

CAPE LOOKOUT NATIONAL SEASHORE

CORE BANKS (NPS) Barrier islands. Northern end adjacent to Ocracoke Inlet

Dynamics: Storm overwash, islands erosional, Cape Lookout migrating east (1864 to 1957) and building to the southwest

NEW DRUM INLET Constructed inlet created by dredging 3.2 km south of closed Drum Inlet in 1971 on recommendation of NPS. No longer maintained

Dynamics: Inlet rapidly widened and shoaled after opening

Structures: None

Dredging: 291,000 m^3 from 1972 to 1974. Discontinued

BARDEN INLET Natural and maintained inlet

Dynamics: Relatively stable protected inlet, tide dominated sedimentation

Structures: None

Dredging: 21,000 m^3/y to 26,000 m^3/y placed adjacent to channel

Effects of Modifications: Minimal. Dredging potentially exacerbates natural erosion of Core Banks side of channel

Mitigation Efforts: Dredged sediments placed near eroding section of Core Banks near lighthouse has arrested erosion. Dredged sections of channel have been relocated

Recommendations: Continue to monitor inlet sedimentation and place dredged sediments in nearshore locations to be determined by on-going beach and bathymetric monitoring program

SHACKLEFORD BANKS (NPS) Barrier Island, downdrift of Beaufort Inlet, updrift of Barden Inlet

Dynamics: Island stable along seaward side (eroded 2.5 m/y, 1936 to 1974), minor accretion at both ends. The sand spit at Beaufort Inlet is sometimes erosional due to shoaling on the opposite side of the inlet

Littoral Drift: 171,000 m^3/y to the east

BEAUFORT INLET Modified and maintained inlet, large ebb-delta system

Dynamics: Active inlet. Strong ebb-tidal currents deflect littoral drift sediments to the east, limiting transport of littoral drift sediments into the inlet and cause erosion on Bogue Banks. Marginal flood currents cause deposition on the west end of Shackleford Banks and in flood delta shoals

Structures: Terminal groin, radial groins, revetments and seawalls on Fort Macon Point (Bogue Banks) have partially stabilized the inlet. Groins on bay side of Shackleford Banks have minimal impact

Dredging: 481,000 m^3/y [1936 to 1974] deposited offshore. In 1986, 2,982,000 m^3 of sediment from inner harbor placed on Bogue Banks beaches. Further placement of inner harbor material on Bogue Banks proposed for 1994

Effects of Modifications: Dredging the ship channel to a depth of -10.7 m MLW has caused a net loss of sediment from the system and a loss of 183,000 m^3/y (75% of the total erosion) from Shackleford Banks. Dredging to a depth of -12.8 m MLW will cause an estimated additional loss of 76,000 m^3/y to Shackleford Banks

Mitigation Efforts: Monitoring includes beach profiling and aerial photo surveys of Shackleford Banks and Bogue Banks began when dredge depth increased to -12.2 m MLW in 1978. Beach nourishment on Bogue Banks. Nearshore berm disposal sites are proposed for dredged material if channel depth is increased to -13.7 m MLW in 1994

Recommendations: Continue beach monitoring. Also conduct bathymetirc survey of inlet ebb-delta as part of monitoring plan. Place dredged sediments in nearshore locations based on results of beach and bathymetric monitoring program

BOGUE BANKS Updrift barrier island

Dynamics: Island stable, erosional (1.3 m/y, 1936 to 1974) on ocean side, stable on Ft. Macon Point

Littoral Drift: 289,000 m^3/y along east end of Bogue Banks, to east

CUMBERLAND ISLAND NATIONAL SEASHORE

CUMBERLAND ISLAND & LITTLE CUMBERLAND ISLAND (NPS) Updrift barrier islands

Dynamics: Stable, accretional on seaward side (averages 1.5 m/y from 1857 to 1991), sand fillet accretion near jetty. Erosional on landward side in some locations

Littoral Drift: Net to the south but contradicted by sediment deposit surveys

ST. MARYS INLET Modified and maintained inlet

Dynamics: Relatively stable protected inlet, ebb-tide dominated sedimentation

Structures: Jetties since 1881, groins on Amelia Island in inlet channel

Dredging: 136,000 m^3/y, placed offshore from 1965 to 1979

Effects of Modifications: Jetties cause inlet to become littoral trap. Dredging causes net loss of sediment from the littoral drift system exacerbating the natural erosion on seaward side of Amelia Island. Ebb delta moving offshore due to jetties and dredging

Mitigation Efforts: 2,597,000 m^3 of dredged sediments pumped on northern and central Amelia Island beaches (1981 to 1992)

Recommendations: Continue Kings Bay Environmental Monitoring Program. Dredged sediments must be placed in nearshore locations to be determined by on-going beach and bathymetric profiling of ebb delta and adjacent nearshore areas

AMELIA ISLAND Downdrift barrier island adjacent to St. Marys Inlet

Dynamics: Island stable, eroding along seaward side, fillet accretion near jetty

Littoral Drift: Net to south

CASTILLO DE SAN MARCOS AND FORT MATANZAS NATIONAL MONUMENTS

VILANO BEACH Updrift barrier island adjacent to St. Augustine Inlet

Dynamics: Stable, erosional on seaward side, sand fillet accretion near jetty

Littoral Drift: Net to the south

ST. AUGUSTINE INLET Man-made inlet, 1940, maintained

Dynamics: Relatively stable inlet, ebb-tide dominated sedimentation

Structures: Jetties 1941 and 1957

Dredging: 1, 316,000 m^3 (1940 to 1986)

Effects of Modifications: 50% of downdrift erosion due to inlet maintenance. Jetties cause inlet to become littoral trap. Dredging causes net loss of sediment from the littoral drift system exacerbating the natural erosion on seaward sides of islands

Mitigation Efforts: 1,224,000 m^3 placed within littoral zone downdrift (1940 to 1986)

Recommendations: Dredged sediments must continue to be placed in nearshore locations downdrift. Maintain seawalls protecting Castillo de San Marcos. Monitor development of shoals northeast of fort

ANASTASIA ISLAND (south end NPS) Barrier island adjacent to St. Augustine and Matanzas Inlets

Dynamics: Island stable, eroding along seaward side, fillet accretion near jetty at St. Augustine Inlet. National Monument property at south end of island is accreting into Matanzas Inlet

Littoral Drift: Net to south

MATANZAS INLET Natural inlet, low maintenance

Dynamics: Relatively stable inlet, ebb-tide dominated sedimentation

Structures: Bridge rebuilt 1992 to 1993. Concrete and sheetpile seawall protects south bridge abutments. Relocated Intracoastal Waterway protected by sheetpile dike on Rattlesnake Island (NPS). Fort Matanzas protected with revetment and short groins. Inland side of Anastasia Island (NPS) protected with 7 short groins

Dredging: Inlet dredging is minimal, placed downdrift. Dredging in Intracoastal Waterway may impact NPS property

Effects of Modifications: The need to protect the bridge may in the future require inlet stabilization. Inland areas of Fort Matanzas National Monument have been armored

Mitigation Efforts: Dredged sediments placed on downdrift beaches (1970s)

Recommendations: Set-up monitoring program and resource management database. Appropriate agencies should maintain armored sections of NPS property if necessary. Dredged sediments from inlet must be placed in nearshore locations to be determined by on-going beach and bathymetric profiling of ebb delta and adjacent nearshore areas on Anastasia Island (NPS)

SUMMER HAVEN Downdrift barrier island

Dynamics: Island stable, eroding along seaward side, fillet accretion near jetty

Littoral Drift: Net to south

CANAVERAL NATIONAL SEASHORE AND MERRITT ISLAND NATIONAL WILDLIFE REFUGE

PONCE DE LEON INLET Modified and maintained inlet

Dynamics: Active inlet

Structures: Jetties, weir and sand impoundment basin 1971

Dredging: 2,828,000 m^3 from channel (1971 to 1990)

Effects of Modifications: Impoundment of sediments at the inlet may have caused net loss of sediment from the littoral drift system exacerbating the natural erosion on seaward sides of adjacent islands

Mitigation Efforts: 1,434,000 m^3 placed on beach north of inlet (1971 to 1990). 442,000 m^3 placed on beach south of inlet. 688,000 m^3 placed on nearshore locations south of inlet (1971 to 1990)

Recommendations: Continue placement of dredged sediments on beaches or on nearshore sites downdrift

NEW SMYRNA BEACH AND BETHUNE BEACH Downdrift barrier, adjacent to Ponce de Leon Inlet

Dynamics: Island stable, erosional (1936 to 1962), accretional (1971-1977) along seaward side

Littoral Drift: 80,300 m^3/y net to south (1969 to 1975). 99,400 m^3/y net to north 1976

APOLLO BEACH, KLONDIKE BEACH, PLAYALINDA BEACH (NPS) Downdrift barrier island

Dynamics: 16 km south of Ponce de Leon Inlet. Island stable, eroding along seaward side

GULF ISLANDS NATIONAL SEASHORE (EAST ISLANDS)

SANTA ROSA ISLAND (NPS) Barrier Island, adjacent to and updrift of Pensacola Inlet

Dynamics: Island relatively stable along seaward side, eroding in some sections and on the western end

Littoral Drift: 200,000 m^3/y to the west

PENSACOLA PASS Maintained inlet

Dynamics: Active inlet with ebb-tidal shoals

Structures: Radial groins at Ft. McRee (Perdido Key) have provided some erosion protection to the fort. Groins on bay side of Santa Rosa Island have minimal impact

Dredging: Approximately 600,000 m^3 were dredged every 2 years and deposited offshore and on Perdido Key prior to 1985. Since then, dredged sediments are, as a matter of practice, kept within the littoral drift system

Effects of Modifications: Dredging the ship channel to a depth of -14.6 m (-48 ft) MLW has caused a net loss of sediment from the system. An interruption of the sediment transport of 200,000 m^3/y causes a loss of 100,000 m^3/y from Perdido Key

Mitigation Efforts: Monitoring of Perdido Key was carried out between 1974 and 1984. In 1985 443,000 m^3 was placed by pipeline dredge on Perdido Key. Placement of 4,590,000 m^3 of dredged material on a 5 km section of the eastern end of Perdido Key and 2,600,000 m^3 in nearshore locations was completed in 1991

Recommendations: Continue comprehensive monitoring program proposed by NPS. Place dredged sediments in nearshore locations based on results of beach and bathymetric monitoring program

PERDIDO KEY (NPS) Downdrift barrier island adjacent to Pensacola Inlet

Dynamics: Island stable, erosional (1.3 m/y, 1974 to 1984) on ocean side, stable or accreting at Pensacola Pass

Littoral Drift: At Perdido Pass 153,000 m^3/y to the west

PETIT BOIS ISLAND (NPS) Barrier Island 10 km in length, adjacent to and updrift of Horn Island Pass

Dynamics: Island migrating westward 52.2 m/y (187 ft/y); approximately 6.9 km (4.3 mi) since 1856. Island is relatively stable along seaward side, eroding on the eastern end; 14 km (8.7 mi) since separation from Dauphin Island

Littoral Drift: 122,000 m^3/y (159,000 yd^3/y) to the west

HORN ISLAND PASS (PASCAGOULA SHIP CHANNEL) Maintained ship channel

Dynamics: Active inlet

Dredging: Begun prior to 1918. Approximately 230,000 m^3/y dredged from pass and placed on sand islands in Mississippi Sound and in nearshore gulf water -6 m. Relocation of channel about 152 m downdrift (west) will provide space for impoundment basin

Effects of Modifications: Permanent placement of the Horn Island Pass channel in 1940 impedes westward migration of Petit Bois Island

Recommendations: Review COE feasibility study recommending that the Pascagoula Ship Channel not be relocated east (updrift) of Petit Bois Island due to high costs and environmental impact.

HORN ISLAND (NPS) Barrier Island 20 km in length, approximately 5 km downdrift of Horn Island Pass

Dynamics: Island migrating westward. Relatively stable on seaward side, eroding on the eastern end

Littoral Drift: Estimated to be 122,000 m^3/y to the west based on Ship Island

DOG KEY PASS Natural Inlet

EAST & WEST SHIP ISLANDS (NPS) Barrier Islands, approximately 12 km total length, updrift of Ship Island Pass (Gulfport Ship Channel)

Dynamics: Islands migrating westward; approximately 11.6 m/y since 1848.

Littoral Drift: 122,000 m^3/y to the west

SHIP ISLAND PASS (GULFPORT SHIP CHANNEL) Maintained ship channel

Dynamics: Active inlet

Dredging: Begun prior to 1918. Approximately 122,000 m^3 dredged annually and deposited on sand islands in Mississippi Sound, and near Cat Island and in gulf locations in water depths of -6 m

Effects of Modifications: Location of the Ship Island Pass channel in the past impeded westward migration of West Ship Island

Mitigation Efforts: Relocation of ship channel approximately 580 m downdrift (west) was completed in 1992. Construction dredging plans show removal of 4,143,000 m^3 from new channel

Recommendations: Monitor Ship Island migration (should migrate west unimpeded for 50 years)

4.0 Cape Hatteras National Seashore

4.1 Introduction

Cape Hatteras National Seashore (NS), North Carolina, is part of a 320-km (200-mi) string of barrier islands known as the "Outer Banks." Inman and Dolan (1989) describe the Outer Banks as a "classical example of a transgressive barrier island coast with cuspate headlands." The sandy islands and their inlets are in a state of constant movement as a result of the highly dynamic coastal environment. The ocean coasts of the barrier islands are receding under the influence of sea level rise, storm wave action, and loss of littoral sediments to inlet shoals, inlet dredging and deposition on Diamond Shoals. Although it is generally believed that the North Carolina barrier island chain north of Cape Hatteras is transgressing landward (Inman and Dolan, 1989), there is evidence that many of the Outer Banks islands are eroding on both the ocean and bay sides and not migrating landward (USACE WD, 1980, 1983a).

Cape Hatteras NS, located in the central section of the Outer Banks, is comprised of three island areas: the southern 14.5 km (9 mi) of Bodie Island, Hatteras Island and Ocracoke Island (Fig. 2). The seashore extends approximately 126 km (78 mi) along the Atlantic Coast and is managed by the National Park Service (NPS). The Fish and Wildlife Service manages Pea Island National Wildlife Refuge located on the north end of Hatteras Island (this area is known as Pea Island). With the exception of eight villages, the island properties were designated a national seashore by Congress on 17 August 1937.

At present, inlets separating Cape Hatteras NS islands include Oregon Inlet to the north, Hatteras Inlet, which is approximately 64 km (40 mi) southwest, and Ocracoke Inlet approximately 28 km (17 mi) further southwest. Originally opened by north Atlantic storms, Oregon Inlet and Hatteras Inlet are used by commercial and recreational vessels operating between Pamlico Sound and the Atlantic Ocean. Ocracoke Inlet has been open through recorded history and also serves as a natural outlet for freshwater from the Neuse and Tar-Pamlico River systems. Of the three inlets, Oregon Inlet is dredged annually and is modified with a terminal groin for stabilization and a revetment for protection of bridge footings on its southern shoulder.

4.2 Oregon Inlet

Since 1585 there has been an inlet in the general vicinity of present-day Oregon Inlet except for the period from 1808 to 1846. At various times, at least 12 natural inlets cut through the Outer Banks north from Cape Hatteras to False Cape at the Virginia border. For example, New Inlet, located approximately 15 km (9 mi) south of Oregon Inlet, was open from 1833 to 1846, shoaled over time, closed in 1922, and periodically reopened. During a hurricane in 1846, the modern Oregon Inlet opened and was named for the first ship passing through. Today, only Oregon Inlet remains open in the nearly 200 km section of barrier island north of Cape Hatteras to Cape Henry (Fig 3).

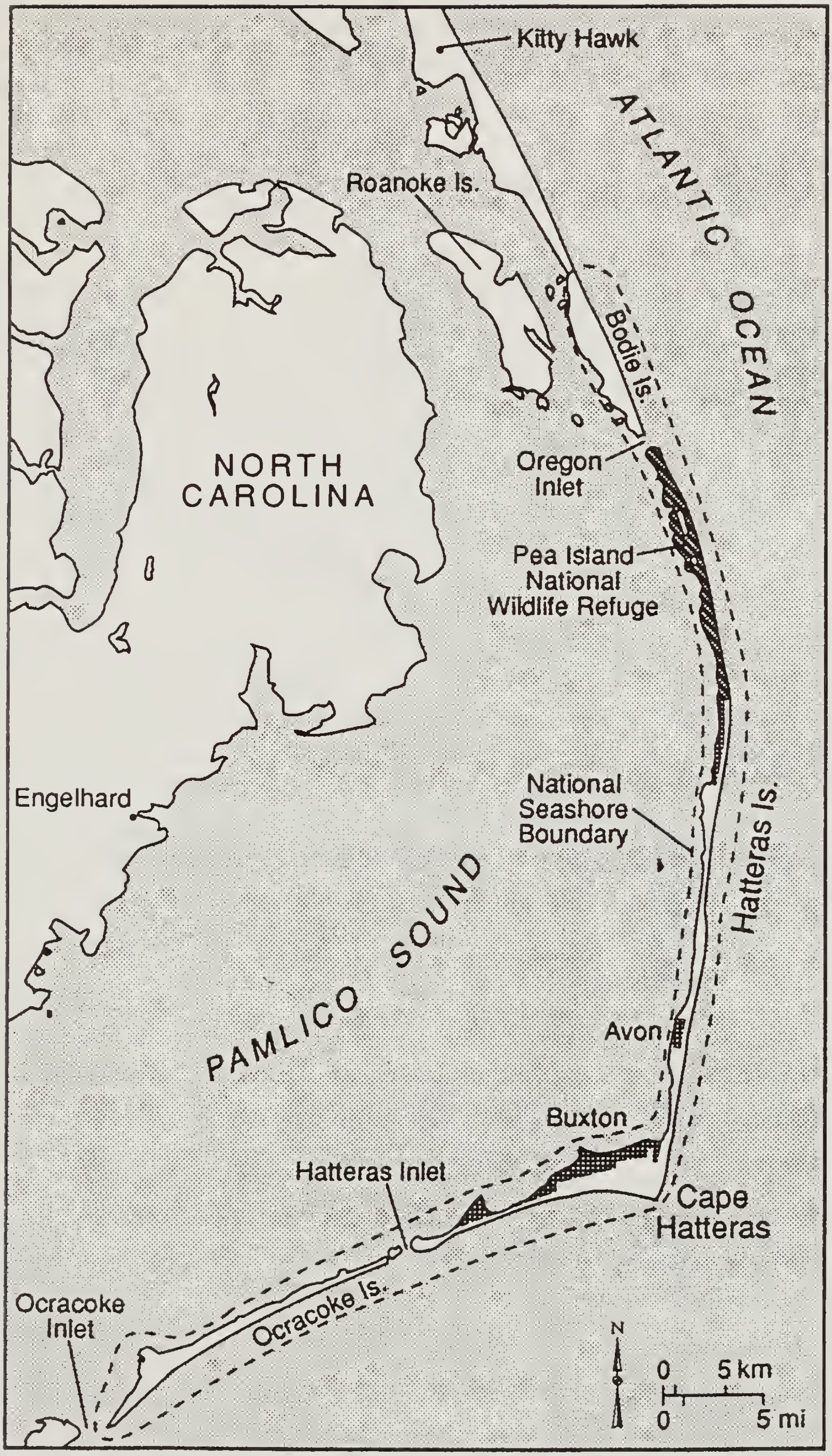

Fig. 2. Cape Hatteras National Seashore, North Carolina.

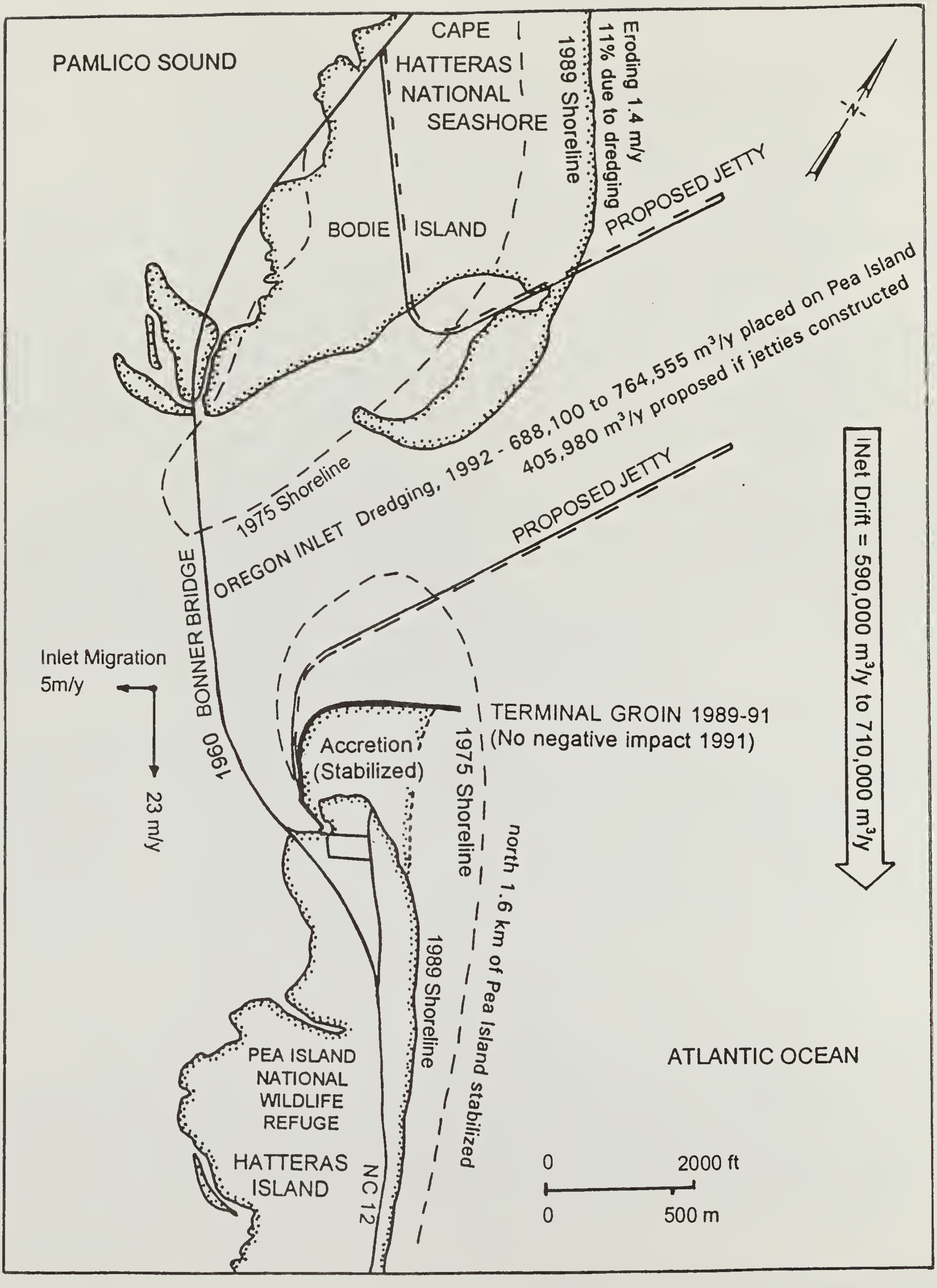

Fig. 3. Oregon Inlet, Cape Hatteras National Seashore, North Carolina.

Oregon Inlet is the most dynamic inlet in the southeastern region of the National Park Service (NPS). For the period 1849 to 1975, Oregon Inlet migrated 2.83 km to the south (azimuth 152°T) at an average rate of 23 m/y (Inman and Dolan, 1989). Between 1981 and 1988 the rate of movement increased as both shoulders migrated southward at a rate of approximately 55 m/y (180 ft/y). The erosion at the southern shoulder accelerated to 350.5 m/y (1,150 ft/y) between April 1988 and March 1989, and during the severe "nor'easter" of 6-10 March 1989, an additional 106.7 m (350 ft) to 212.9 m (400 ft) of Pea Island was eroded (Corps of Engineers [COE], May 1989).

Historically, the normal width of Oregon Inlet during storm-free periods has been approximately 640.1 m (2,100 ft); however, following the active storm periods of 1931 to 1945 and 1954 to 1962, Oregon Inlet widened to 1,270 m (4,170 ft) and then to 2,180 m (7,150 ft) by 1962. These changes in width and variation in the location of the inlet and channel have been primarily associated with severe winter storms that have tended to widen the inlet by erosion of both the northern (Bodie Island) and southern (Pea Island) shoulders of the inlet. During times of less dynamic conditions, the inlet has narrowed considerably. This narrowing normally occurs from the north, with the southern shoulder showing little tendency toward northward movement (Dean, 1988).

The Cape Hatteras NS is part of a longshore sand-transport system that contains the largest gross and net volume of sediments in the southeastern region of the National Park Service (NPS). Inman and Dolan (1989) estimated the littoral drift in the Oregon Inlet area to be 1,180,000 m^3/y (1,543,000 yd^3/y) to the south and 470,000 m^3/y (615,000 yd^3/y) to the north. This gives a gross (southerly plus northerly) transport rate of 1,650,000 m^3/y (2,158,000 yd^3/y), and a net southerly drift of 710,000 m^3/y (929,000 yd^3/y). These figures are in close agreement with results of a COE detailed sediment budget analysis where net southerly littoral drift was calculated at 879,000 m^3/y [1,150,000 yd^3/y] (Inman and Dolan, 1989 after USACE WD, 1980, and Jarrett, 1978).

4.21 Inlet Modifications

The Federal entrance channel project at Oregon Inlet was authorized in 1950. The project was started in 1960 and the channel configuration was specified to be -4.2 m (-14 ft) at mean low water ("MLW") and 122 m (400 ft) wide. Following construction of the Herbert C. Bonner Bridge across Oregon Inlet between Bodie and Pea Islands for NC Highway 12, maintenance dredging was initiated in 1962 and materials averaging 320,000 m^3/y, were disposed offshore using hopper dredges. From 1965 to 1983 sidecast dredges were used, keeping the dredged materials in the inlet. In 1983, hopper dredges were reintroduced and sidecast dredging continued.

In addition to deep-water disposal of sediments from the longshore sand-transport system, other factors may also have had significant impact upon seashore property. The COE (USACE WD, 1970) reported that the on-going effect of alternate widening and narrowing of Oregon Inlet, the relocation of the primary channel in 1960, and the southerly migration of the inlet since bridge construction was completed, created an erosional threat to the bridge abutment and the Coast Guard Station. Further, hazardous navigation conditions in the channel continued to be a serious problem for vessels passing through the inlet.

From 1983 to 1989 approximately 550,000 m^3 (719,000 yd^3) were dredged annually to maintain the -4.3 m (-14 ft) inlet bar channel and were deposited in water depths exceeding -6.1 m (-20 ft). "Due to this substantial depth, it is questionable whether this placement provides significant benefit to the downdrift shoreline" [of Pea Island] (Dean, 1988).

In 1989, the NCDOT reported a decrease in the natural sand by-passing efficiency at Oregon Inlet causing accelerated erosion of the north end of Pea Island during the late 1980s. The authors suggested several factors exacerbating Pea Island erosion. These include natural deposition of 3,500,000 to 4,000,000 yd^3 of sand on updrift Bodie Island beaches and recurved spit (north shoulder of inlet), increased quantities of sediments dredged from 1985 to 1989, and growth of the flood shoal on the south side of Oregon Inlet (possibly caused by the bridge abutment). Beach profile surveys by the COE show an average erosion rate of 45 ft/y for the northern 6000 ft of Pea Island and 13 ft/y for the next 6000 ft south for the period 1985 to 1989.

To address these problems, a 1,105-m (3,625-ft) revetment and terminal groin were designed for the NCDOT to stabilize the northern 610 m (2,000 ft) of Pea Island. The project was approved in 1988 and construction began in 1989 with completion in April 1991. The plan included permanent entrapment of 382,000 m^3 to 764,500 m^3 (500,000 yd^3 to 1,000,000 yd^3) of sand that would have otherwise been transported into the inlet. The COE monitoring showed the northern shoulder of Pea Island rebuilding as fast as the terminal groin was constructed (COE, 1989). As part of the plan, NCDOT agreed to fund beach nourishment if historical erosion rates were exceeded by 191,100 m^3 (250,000 yd^3) per 1.61 km (1 mi) on downdrift beaches. The monitoring plan begun in 1989 (prior to completion of the groin) showed no measurable adverse impacts on 9.66 km (6 mi) of downdrift beaches after one year (Overton, Fisher and Dolan, 1991).

After the NCDOT began construction of the terminal groin and revetment, deposition of dredged material has continued in approximately -6.1 m (-20 ft) of water off Pea Island. According to a COE (USACE WD, 1983) study, sands that are deposited at a minimum depth of -5 m (-17 ft) are dispersed onshore at an annual volume rate of transport of about 25%. Disposal of the material in shallower water was not considered practical as the draft of a hopper dredge is 4.3 m (14 ft), posing a possible grounding hazard near-shore. According to Inman and Dolan, 1989, the placement of dredged material in -6.1 m (-20 ft) of water has not prevented the erosion that has occurred along the northern 3.2 km (2 mi) of Pea Island south of the Coast Guard Station. In 1992, at a cost of about $3,000,000, approximately 689,000 to 765,000 m^3 (900,000 to 1,000,000 yd^3) of material was removed from the vicinity of the Bonner Bridge and placed on Pea Island. This operation will be repeated in 1993 and may become an annual requirement due to the present configuration of shoals in the inlet complex. It is estimated that it will cost between $6,000,000 and $7,000,000 to maintain the existing 4.3 m (14 ft) ocean bar channel and 3.7 m (12 ft) interior channels (Tom Jarrett, Wilmington District, USACE WD, personal communication, 1993).

An important issue raised by the NPS and the Fish and Wildlife Service is the question of the impact of barrier island landward migration on the proposed Oregon Inlet

jetties. If the islands are transgressing landward the jetties would have to be extended landward over time. However it has been shown that over the 94 year period between 1852 and 1946 Hatteras Island (between Pea Island National Wildlife Refuge and Rodanthe, 21 km south of Oregon Inlet) rising sea level did not cause landward migration of the barrier. Rather, a seaward (not landward) expansion of marshes and erosion on both sides of the barrier was observed (COE, 1980). If this trend continues, the necessity for extension of Oregon Inlet jetties to accommodate barrier island transgression becomes a non-issue.

4.22 Inlet Effects

Inman and Dolan (1989) in their analysis of the Outer Banks, and particularly the sediment budget estimated for 32 km (20 mi) of shoreline centered at Oregon Inlet, found that channel dredging at Oregon Inlet (using a figure of 320,000 m^3/}) was responsible for 11% of a measured annual mean shoreline recession for that area of the Outer Banks of 1.4 m/y (4.6 ft/y). They report that the "offshore placement of dredge material constitutes a continuous loss of mass to the barrier system." Further, they found that the offshore placement of 320,000 m^3/y (418,500 yd3/y) account for "almost one-half of the increased erosion rate (2.6 m/y [8.5 ft/y]) between the inlet and Rodanthe." In order to maintain many of the values and functions of the seashore, the need for bypassing dredged material at Oregon Inlet and the need for beach nourishment in eroded areas is clear. The 1992 sand bypassing project addresses these needs and is proposed to be continued.

As recently as March, 1992, COE plans were approved to stabilize the inlet with two jetties. Plans include summer season sand transfer of approximately 406,000 m^3/ (531,000 yd^3/y) from the north jetty accretion fillet to the north 3 miles of Pea Island beaches via a floating pipeline dredge. The plans were authorized in 1970 and have an estimated construction cost of $87,000,000 and annual maintenance cost of $6,250,000. In addition to the inlet stabilization project, the Bonner Bridge is scheduled to be completely replaced within the next 10 to 15 years. If the jetties are built, the monitoring will be a joint effort by the COE and the State of North Carolina.

A dredge-only option to the jetties was proposed by the NPS and was considered by the COE (USACE WD, 1983). The COE reported that the year-round dredging of 1,109,000 m^3/y (1,450,000 yd^3/y) disposed in -5 m (-17 ft) would result in catastrophic and unacceptable erosion along the northernmost 5 km (3 mi) of Pea Island. Alternative placement of the dredged materials directly on eroding beaches by pipeline would minimize the problem of erosion. However the impact of beach placement of 1,000,000 m^3/y (1,308,000 yd^3/y) would be large and is also contrary to the NPS policy of minimal impact on natural processes. A third option proposed by the NPS called for hopper dredging and offshore deposition, followed by pipeline transfer of the material back to Pea Island beaches. This option was rejected by the COE as too costly. A two-year dredge-only demonstration project was proposed by Dean, 1988.

4.23 Summary and Recommendations:

Cape Hatteras NS has been, and continually is, dramatically affected by natural processes. The seashore has been further modified by channel maintenance at Oregon Inlet, one of the most dynamic inlets on the eastern seaboard. Because of the large quantities of sand moving into the inlet, dredging costs are high, averaging $3,351,000 per year from 1985 through 1989. Primary channel relocation and dredging, the removal of dredged materials from the longshore sand-transport system by deposition in deep waters, construction of Bonner Bridge, and subsequent construction of protective revetment and terminal groin for the bridge abutments and highway-approaches, as well as the planned construction of the jetties may have significant long-term effects on the adjacent seashore.

Stabilization of the inlet has begun with the construction of the terminal groin and revetment. Subsequent monitoring shows the inlet to be stable with respect to migration and no increase in downdrift beach erosion has been observed. If monitoring studies indicate increased erosion attributable to the terminal groin, Pea Island beaches will be nourished at the expense of the North Carolina Department of Transportation (NCDOT). Since 1992, dredged materials have been placed on Pea Island Beaches.

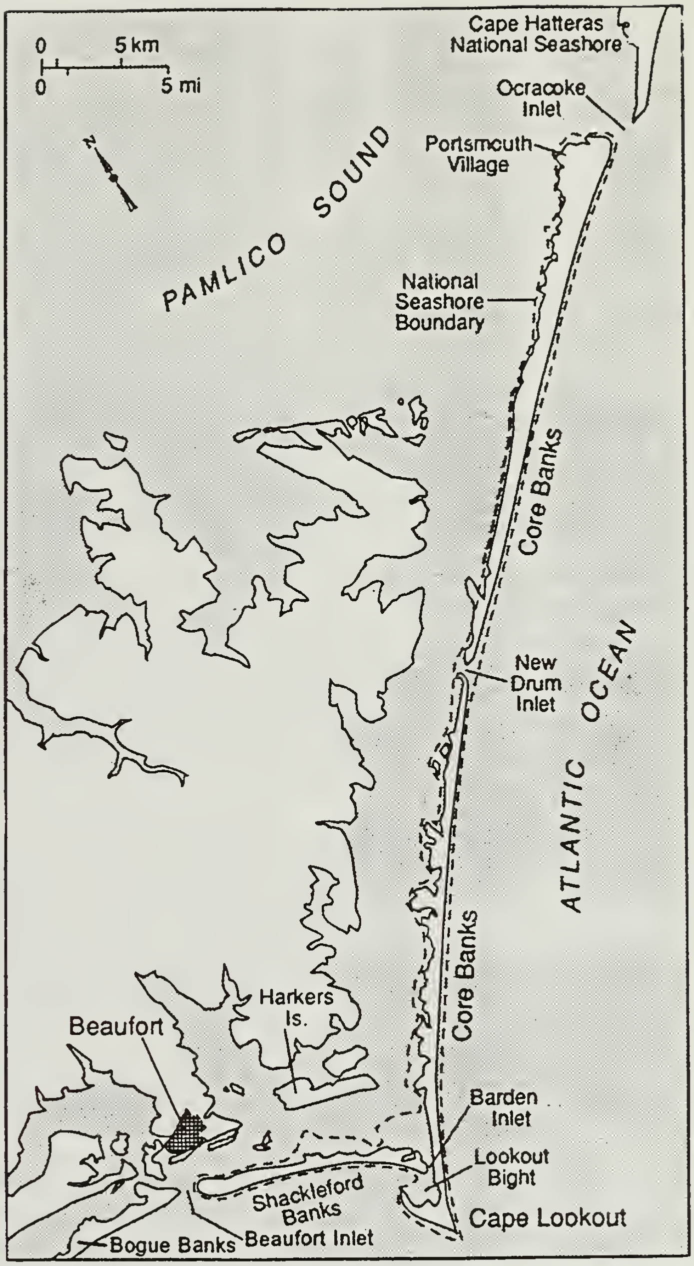

Fig. 4. Cape Lookout National Seashore, North Carolina.

A question that needs to be addressed for Oregon Inlet is what scheme has a greater environmental impact on the barrier islands: dredging and placement of large quantities of sediment on or near barrier island beaches, or jetty channelization and dredging and placement of smaller quantities of sediment.

1) Coordinate monitoring efforts in an on-going Oregon Inlet management and monitoring program (Modeled on the Kings Bay project) using experts representing the NPS, COE and NCDOT.

2) Closely monitor changes in nearshore bathymetry as well as monitoring beach profiles.

3) In order to maintain the net volume of littoral drift and minimize downdrift erosion on Cape Hatteras NS, all dredged materials must continue to be placed within the littoral drift system. The GPS/GIS data in addition to COASTS data (Dolan et al, 1979) will indicate those areas where dredged materials should be placed.

4) If jetties are not constructed, special focus on inlet migration and shoaling will continue to be necessary. Monitoring movement of the inlet, particularly along the northern shoulder, and more detailed study of adjacent seashore lands on Bodie and Pea Islands via GPS/GIS shoreline and bathymetric profiling are recommended.

5) We further recommend that NPS undertake an alternative-use feasibility study for impacted seashore lands particularly those that are stabilized by structures or disturbed by the continuous beach nourishment activities on Pea Island.

5.0 Cape Lookout National Seashore

5.1 Introduction

Cape Lookout NS was authorized as a national seashore by Congress on 10 March 1966. Less dynamically energetic, but similar in geology and ecology to Cape Hatteras NS to the north, Cape Lookout NS continues and completes the long chain of barrier islands that make up the Outer Banks of North Carolina (Fig. 4). High winds, hummocks, dunes, shrub and grasslands, rip-currents, and changing conditions in the channels characterize the park.

The seashore is composed of three barrier islands and the east end of Harkers Island. Core Banks includes two of the barrier islands and runs northeast-southwest for approximately 89 km (55 mi). Shackleford Banks, to the south, runs east-west for approximately 14 km (9 mi). Unlike Cape Hatteras NS with its long established residence and resort developments, Cape Lookout NS is a wilderness environment, accessible only by boat or ferry. With the exception of the old settlement at Portsmouth Village, the seacoast, the barrier islands, the inlets, and the sheltered Core Sound remain undeveloped. Core Banks has low topography, is often overwashed by storms and is receding. Cape Lookout (a cuspate spit headland) and associated shoals are growing to the south due to a net southerly littoral drift. Shackleford Banks has historically remained in approximately the same location and was connected to the geologically migrating Core Banks between 7000 and 4000 BP (Moslow and Heron, 1981).

Two dynamically active entrance channels are associated with the northern Cape Lookout barrier islands. These include Ocracoke Inlet that separates Ocracoke Island from the Core Banks and New Drum Inlet that is located near the center of Core Banks. Barden Inlet is protected from open ocean storm waves by Cape Lookout, and lies between Shackleford and Core Banks. Beaufort Inlet is located at the western end of Shackleford Banks where it lies in the lee (from North Atlantic storms) of Cape Lookout.

All four channels serve as navigational entrances and as passageways for renewal of water to the sounds and lagoons behind the barrier islands. Barden and Beaufort Inlets are maintained for navigation, and modifications to these inlets have impacted NPS properties. Although Ocracoke Inlet is maintained for navigation, it requires infrequent maintenance and is not discussed here. New Drum Inlet was artificially opened in 1971, was dredged from 1972 to 1974, widened and shoaled rapidly. In response to problems caused by the opening of New Drum Inlet, dredging operations were terminated.

5.2 Barden Inlet

Barden Inlet was formed by a hurricane on 16 September 1933 (Fig. 5). Maps that are dated 1733, 1738, 1770, and 1775 show no inlet in the area, but 1808, 1833, and 1861 maps show an inlet at or near present day Barden Inlet. The 1861 inlet did not last, however, as 1865, 1882, and 1895 maps indicate that the inlet closed and remained so until the hurricane of 1933 (USACE WD, 1978a).

Priddy and Carraway (1978) reported on the position of the shorelines of "Barden's Inlet" from 1943 to 1976 and noted extensive inlet widening since 1933. While the left (western) shoreline had remained "within a few hundred feet" of its original location, the right (eastern) shoreline had moved 457 m (1,500 ft) to the east.

Under natural conditions the net longshore transport of sand along Shackleford Banks is from the west to east. The COE (USACE WD, 1978a) conducted extensive wave energy - sediment transport studies and estimated that the net amount of material moving from west to east toward Barden Inlet is 289,000 m^3/y (378,000 yd^3/y). They further reported (USACE WD, 1978a) that the easterly littoral drift causes inlet migration through accretion of sediment on the west side of the inlet and concomitant erosion on the east side (Core Banks). Tidal current flows are directed at Core Banks due to the natural configuration of the inlet.

5.21 Inlet Modifications

In 1917, a 1,463-m (4,800-ft) rubble-mound breakwater was constructed at the western tip of Cape Lookout to create a harbor of refuge. As a sand spit formed in the lee of the structure no repairs were needed and the structure was deauthorized in 1985.

After Barden Inlet opened in 1933, a channel was approved to improve boat access to Back Sound. The channel configuration of Barden Inlet was 1.5 m x 15.2 m x 6.6 km MLW (5 ft x 50 ft x 4.1 mi) as adopted by the River and Harbor Act of 1937. Maintenance dredging began soon thereafter in spot shoals within the natural inlet channel. In 1956, the channel dimensions were increased to 2.1 m x 30.5 m x 6.6 km MLW (7 ft x 100 ft x 4.1 mi). The average annual quantity of material dredged from the inlet was reported to be 26,000 m^3/y [34,000 yd^3/y] (USACE WD, 1978a). Comparing the annual dredging to the

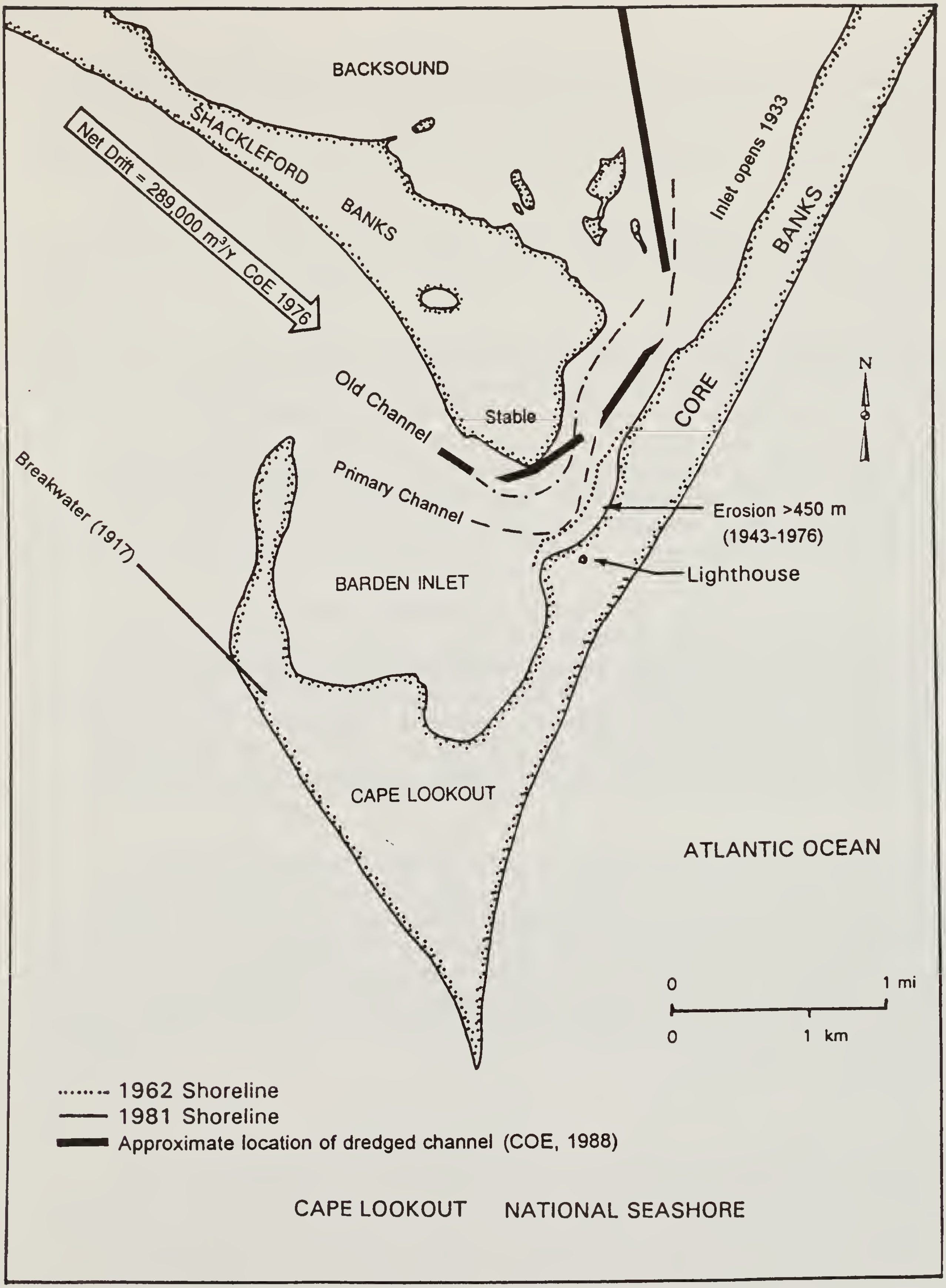

Fig. 5. Barden Inlet, Cape Lookout National Seashore, North Carolina.

amount of littoral drift material moving into the inlet (289,000 m^3/y), "would suggest that natural processes dominate the shoal-channel patterns developing in and around the inlet" (USACE WD, 1978a). This implies that the portion of the channel that passes through Barden Inlet is maintained primarily by natural processes. Between 1979 and 1989 shoaling due to the littoral ebb and flow at Barden Inlet required dredging of approximately 16,500 m^3/y (21,600 yd^3/y) to maintain a navigable channel. As noted below, determining the relative effects on erosion of natural processes versus dredging, became a sticking point in developing plans for controlling the erosion on the east shore of Barden Inlet.

Illustrating the difficulty in researching and evaluating changes that occur in coastal environments, the National Park Service and Coastal Research Associates (CRA) report to the COE (Dolan et al, 1978) summarized the effects and problems of dredging within Barden Inlet channel. "The fact that dredging is required indicates that this Primary Channel has a natural tendency to fill in with sediment. We suggest that the maintenance dredging of the present Primary Channel be stopped and a new channel be dredged through the Secondary Channel and the Old Channel. The existing Primary Channel may then naturally fill in with sediment, reducing the volume of water flowing against Core Banks, and thus reducing or stopping erosion near the Lighthouse."

The COE (USACE WD, 1978b) responded to the NPS "that the issue is one of whether or not dredging contributes significantly to erosion, and, if so, what could be done to eliminate that element of the overall problem" (of natural erosion through the channel). Further, it was noted that all dredging was done with a sidecast dredge (M/V MERRITT), that all materials were simply placed alongside the channel, and that the loss of any material from the system is a natural process in the inlet environment. In addition, the COE pointed out that channel relocation would involve the use of different equipment and result in greater cost.

Over a 37-year period of photographic records, the COE (USACE WD, 1978) reported that, at various times when dredging was occurring or halted, shorelines accreted or eroded in asynchronous ways, with a single exception during the permod of 1972 to 1973, with the "highest rate of shoreline retrogression [erosion] near the Lighthouse, 7.13 m/mo (23.4 ft/mo), occurring during a period in 1977 when there was no dredging." They state "in view of the results of the comparative analysis, it is concluded that there is no apparent direct relationship between dredging operations at Barden Inlet and shoreline movement rates along the sides of the inlet."

5.22 Inlet Effects

From a point measured from the lighthouse on Cape Lookout to the eastern side of Barden Inlet, the shoreline was determined to have eroded towards the lighthouse approximately 9.7 m/y (32 ft/y) over a 37-year period between 1940 and 1977 (USACE WD, 1978). Further, the western side of Core Banks in the area of Cape Lookout, on the opposite side of Core Banks from Barden Inlet, also experienced erosion. Between 1976 and 1978, 37.8 m (124 ft) of shoreline was lost to erosion (USACE WD, 1978).

In a study authorized by the NPS, the Department of the Interior, and the Department of Transportation (Coast Guard), the COE (USACE WD, 1978) developed a series of discussions, recommendations, and three alternative plans for the mitigation of this erosion problem. Among them were the relocation of the channel, the deposition of dredged materials on the eroded site, and the armoring of that site against future erosion.

The three alternative plans for controlling erosion at Barden Inlet were: the placement of stone riprap on the eroding coastal features, the construction of dikes and groins extending from the shoreline into the flow channel, and the relocation of the channel westward of Core Banks [Fig. 5] (USACE WD, 1978). The first and second of these plans was determined to negatively impact the functions and values of the seashore, and the third was considered to be too costly and a constant effort to maintain the channel position against natural processes. As a result the project was not approved at that time. However, the dredged sections of the channel were later relocated to the recommended positions.

Significantly, since 1978, the COE has deposited material as close to the shore as possible, adjacent to the erosion area near the Lighthouse. Since this was done, erosion has decreased in this area and no further action was deemed necessary (Tom Jarrett, Wilmington District, USACE WD, personal communication, 1993).

5.23 Summary and Recommendations - Barden Inlet

Natural channel migration has eroded the west side of Core Banks. Channel maintenance dredging potentially exacerbated the erosion. Placement of dredged materials on nearshore areas of Core Banks and channel relocation have mitigated the problem.

1) Placement of dredged materials as near as possible to eroded areas should continue, particularly adjacent to the lighthouse

2) Maintain new channel configuration

3) The great difficulty in accurately determining shoreline movement comes directly from procedures involved in aerial photography and point-to-point measurements on shore. Because the lighthouse at Cape Lookout provides a fixed point, some of these problems were reduced; however, routine and frequent GPS/GIS mapping for resource management databases would greatly assist NPS in monitoring the effects of erosion along Cape Lookout NS coastline

5.3 Beaufort Inlet

Beaufort Inlet is an active natural inlet located between the relatively stable Bogue Banks to the west and NPS Shackleford Banks to the east (Fig. 6). Overwash is minimal due to high topography on the islands (Berelson, 1979). Five inlet openings and closings over the last 4800 years were mainly responsible for the flood tidal deposits. The latest opening, Beaufort Inlet has remained relatively stable with some fluctuations in the configuration of the shoulders of the inlet.

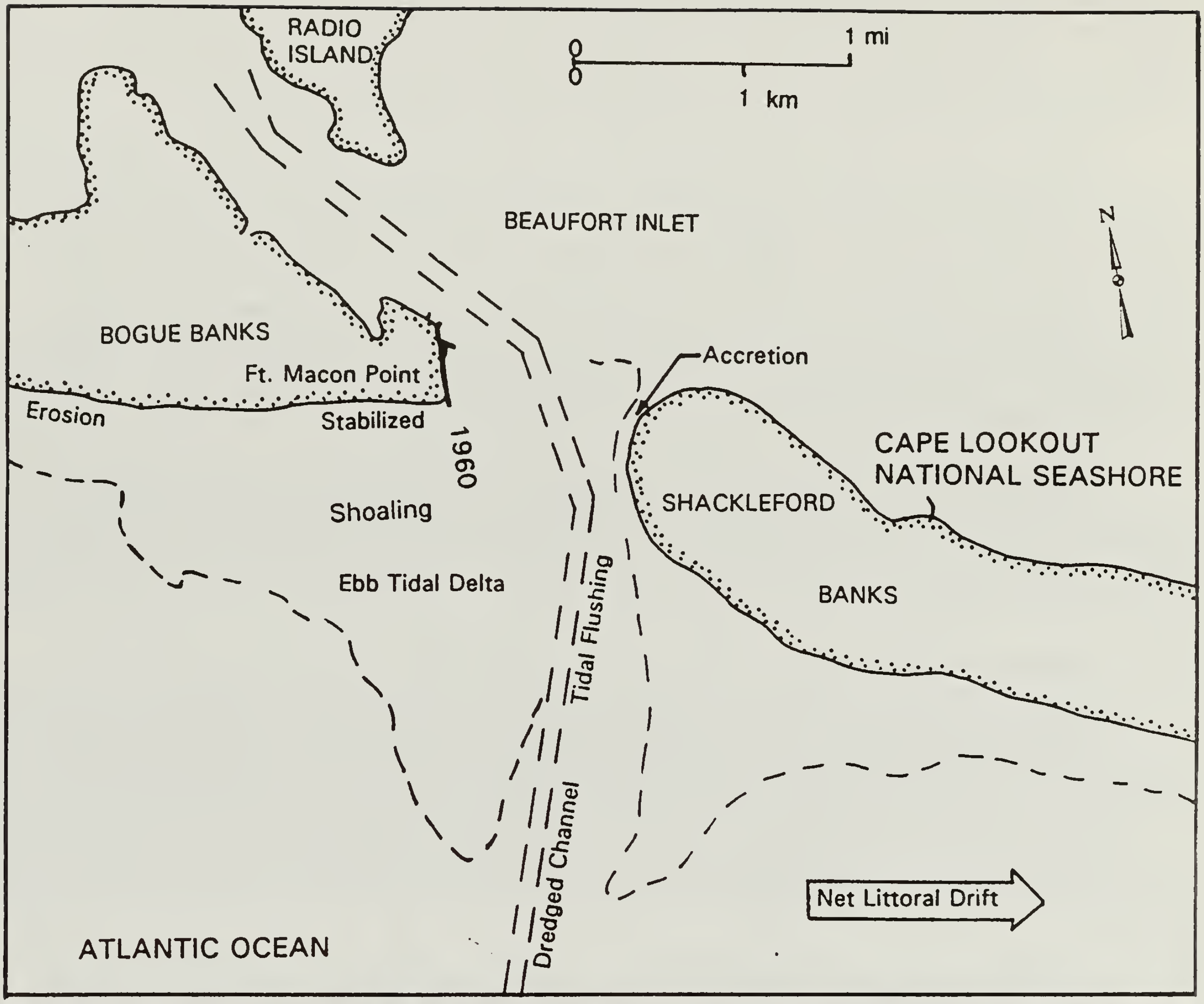

Fig. 6. Beaufort Inlet, Cape Lookout National Seashore, North Carolina. Aerial Photo April 21, 1981.

Shackleford Banks, Beaufort Inlet, and Bogue Banks are subject to severe erosional effects of storm surge, waves, and currents. "An average of 1.64 hurricanes per year affect the Beaufort Inlet area" (Crutcher and Quayle, 1974, cited by Sarle, 1977). This, when coupled with sparsely-vegetated, low-lying western end of Shackelford Banks, creates a very dynamic area, subject to spit migration and overwash.

According to the COE (USACE WD, 1976), Beaufort Inlet can be dated back to 1708. Migration of the channel was permanently arrested in the 1960s by the construction of a terminal groin on the Bogue Banks shoreline and "extensive channelization" and dredging between Shackleford and Bogue Banks. This channel is used primarily for commercial and recreational purposes and serves as an outlet for the Newport and North Rivers.

Prior to, and in conjunction with the addition of Shackleford Banks to the jurisdiction of Cape Lookout NS management in 1978, a variety of studies were undertaken and completed on the history and the dynamics of the inlet and the adjacent shorelines. Sarle (1977) noted that the accretional and erosional patterns on Shackleford Banks were controlled mainly by the morphology and hydrodynamics of the inlet. In 1976, the Shackleford Banks side of the inlet had grown 1,317 m (4,320 ft) westward since 1953 (USACE WD, 1976). By contrast, the Bogue Banks shore of the inlet grew eastward only 70 m (230 ft) prior to construction of a stone revetment, wall and groin at Fort Macon Point (Sarle, 1977). According to Sarle, spit growth on Shackleford Banks between 1953 and 1962 was primarily the result of hurricane storm deposits. Later, 30 m (98 ft) of erosion from 1971 to 1976 was caused by accretion on the Bogue Banks side of the inlet with concurrent ebb channel migration and erosion of the Shackleford spit.

A sediment budget analysis was conducted for the Beaufort Inlet area for the period 1936 to 1974 by the COE (USACE WD, 1976). Calculations showed sediment transport rates to the east along Bogue Banks of 289,000 m^3/y (378,000 yd^3/y) and 98,000 m^3/y (128,000 yd^3/y) to the west along Shackleford Banks. This gives a gross transport rate of 387,000 m^3/y (506,000 yd^3/y) and a net rate to the east of 191,000 m^3/y (250,000 yd^3/y). With dredging and sediment deposition within the inlet, they estimated that 45,873 m^3/y (60,000 yd^3/y) bypassed the inlet to continue east along Shackleford Banks. Klavans (1983 after Johnson, 1956) reported that the littoral drift from southwest of Beaufort Inlet in the amount of 22,560 m^3/y (29,500 yd^3/y) bypasses the inlet, continues along Shackleford Banks and is deposited at Cape Lookout. The westward migration of Shackleford Banks against the net eastward sediment transport presents an interesting dynamic of the Beaufort Inlet area. Coastal inlets typically migrate in the direction of the net littoral drift. The reverse at Beaufort Inlet is explained by Klavans (1983) as due to strong ebb tidal flushing with ebb tidal delta development and flow bypassing of littoral drift sediments seaward of the inlet. Klavans further suggests that the strong ebb current modified by the Coriolis effect causes the erosion on Bogue Banks.

5.31 Inlet Modifications

Since dredging began in 1911, more than 26,760,000 m^3 (35,000,800 yd^3) of material have been dredged from the ocean bar at Beaufort Inlet, deposited in deep water and lost from the system. The average dredging rate was 481,000 m^3/y (29,000 yd^3/y) from 1936 to 1974 (USACE WD, 1976). In 1978, the entrance channel depth was increased from -35 ft to -40 ft MLW. The depth of the project will be increased to -45 ft MLW in 1994. Dredging continues on an annual basis.

The North Carolina Division of Coastal Management (NCDCM, 1986) reported that the Bogue Banks beaches, and specifically Fort Macon State Park at its eastern end, have been nourished by sediments deposited from maintenance dredging of the Beaufort inner harbor (71,000 m^3 [93,000 yd^3] in 1965 and 80,000 m^3 [105,000 yd^3] in 1969, COE, 1976). Historically, and until recent years (NCDCM, 1986), all of the dredged material was disposed of at sea with few exceptions. In 1986, 2,980,000 m^3 (3,900,000 yd^3) of sediment were placed on Bogue Banks from the inner harbor disposal area known as Brandt Island.

5.32 Inlet Effects

Dredging of the ship channel to -35 ft MLW has caused a net loss of sediment from the system and a loss of 183,000 m^3/y [240,000 yd^3/y] (75% of the total barrier island erosion) from Shackleford Banks (USACE WD 1976). Dredging to a depth of -42 ft MLW will cause an additional loss of 76,000 m^3/y (99,000 yd^3/y) to Shackleford Banks.

Both the North Carolina Coastal Management Program and the general policies of the National Park Service have recognized that sediment balance, sand transport, and natural inlet and channel locations have been affected by physical interference with these processes, and that every effort must be exerted to maintain seashore lands and adjoining state parks in their natural condition. Yet, in the case of the Shackleford Banks spit, accretion and migration toward the channel are the general case, and erosion is not a dominant theme. It is generally agreed that some nourishment of Shackleford Banks may be necessary if erosion accelerates in the future. The question remains as to whether dredged sands should be placed "updrift" or "downdrift" of Beaufort Inlet if Shackleford Banks continues to accrete westward.

5.33 Summary and Recommendations - Beaufort Inlet:

Because of the unique dynamics of Beaufort Inlet, the downdrift shore of the inlet, Shackleford Banks spit has typically accreted over time. However it is well documented that channel maintenance dredging has accelerated the natural ocean side recession of the rest of Shackleford Banks. Further, there is growing evidence that the ebb-delta complex has been impacted by dredging.

1) A continuous program of bypassing net volumes of littoral drift sediments is recommended. In order to establish rates of shoreline and bathymetric change and distribution of dredged sediments, accurate mapping and a coordinated multi-agency monitoring program is necessary to establish a strong body of baseline data.

2) Rather than disposal at sea, dredged materials should be kept in the system and placed in nearshore locations or on beaches as needed. Proper placement of these sediments is an important issue that can be addressed through beach and bathymetric monitoring of the ebb-delta complex.

6.0 Cumberland Island National Seashore

6.1 Introduction.

Cumberland Island NS encompasses Little Cumberland Island, several small islands and Cumberland Island, the largest and most southern of Georgia's barrier islands (Fig. 7). These mesotidal islands are known for their wildlife, well-established hammock and dune topography, historic structures and one of the largest remaining maritime forests in the United States. Extensive salt marshes, and tidal creeks and flats, are found on the landward sides of the islands. Private residences existed on Cumberland Island prior to the seashore's establishment on 12 October 1972. Today, the island has been allowed to revert to a natural condition and few of the residences remain. The northern half of the seashore has been designated as a wilderness area. Accessible only by boat and ferry, the island is approximately 26 km (16 mi) long and 1 to 3 km wide (0.6 to 2 mi) wide. Elevations on the island range from sea level to 13 m [40 ft] (Griffen, 1984).

The Cumberland Island region has a unique physiologic history greatly unlike the formation of islands along the Outer Banks. Cape Hatteras NS and Cape Lookout NS are characterized by long, narrow, eroding barrier islands with active inlets migrating down a wave-and-current dominated coast. In contrast, Cumberland Island and its associated tidal islands in the Georgia Embayment can be described as wide, stable beach-ridge barriers and sediment deposits of tides and rivers, that are 2,000 to 4,000 years old (Oertel, 1979, and Nummendal, et al., 1977). According to Nummendal, et al., 79% of the lagoonal area draining through St. Marys Inlet is covered by marshland.

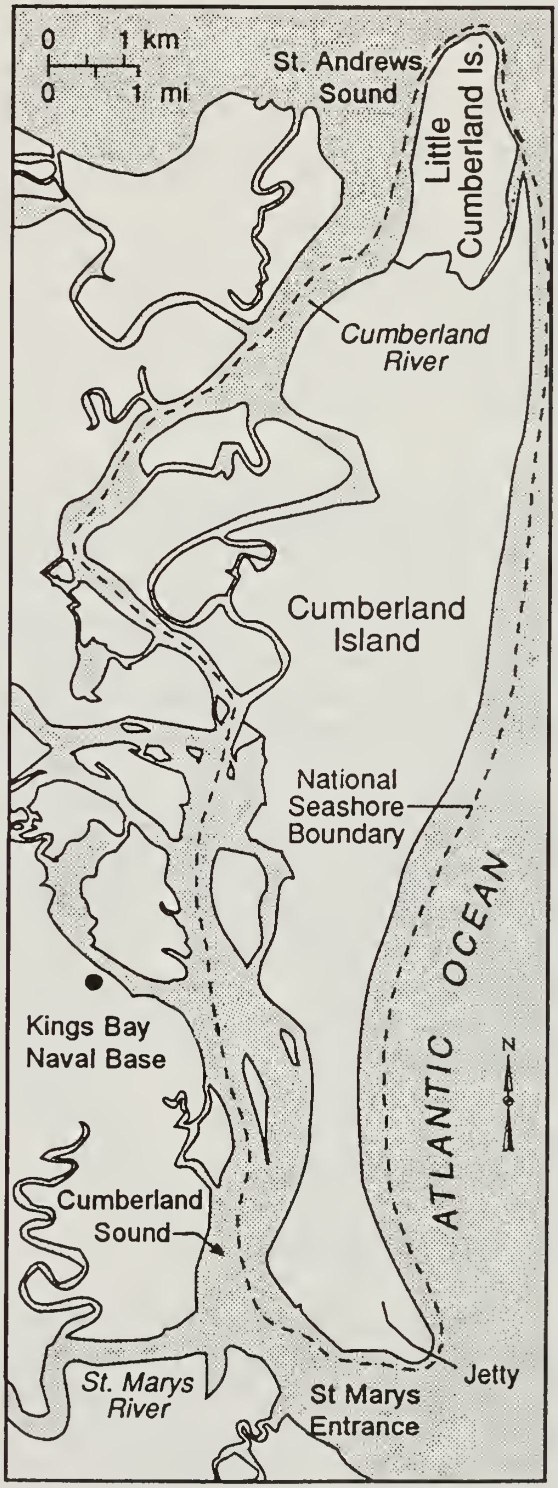

Fig. 7. Cumberland Island National Seashore, Georgia.

Cumberland Island is typical of South Carolina and Georgia coastal barriers known as Sea Islands. The wide tidal range (mean: 1.8 m, 6 ft) and low average wave energy allow for formation and maintenance of inlets without being sealed by wave driven longshore sand transport. A result is a widespread ebb-tidal delta system of shoals and sediment deposits lying seaward of a typical inlet in this region.

Cumberland Island is bounded by St. Andrew's Sound and the Cumberland River (to the north and west), and Cumberland Sound, St. Marys Inlet, and Amelia Island, FL, (to the southwest and south). The St. Mary Inlet, at the Florida/Georgia border, is a federally maintained entrance channel to the Intracoastal Waterway that provides access to recreational, commercial and military vessels. It opens to the ports at Fernandina, Florida and St. Marys, Georgia, and Kings Bay Naval Submarine Base, Georgia (Fig. 8). To maintain channel depths and location, the inlet is protected with rubble-mound jetties and is periodically dredged. Historically, St. Andrews Sound and the Cumberland River to the north and west have not provided the same access for the larger vessels. Therefore, no modifications to the shoreline have occurred in that area of the park.

Erosion on the islands has typically been caused by hurricanes and nor'easters bringing high winds, elevated tides, and powerful storm surges (Parchure, 1982). The predominant winds in the area are from the northeast in the winter and fall (Florida Coastal Engineers, 1976, cited by Parchure, 1982), but some tropical storms come ashore, reverse their direction, and pass back across St. Marys and move out to the Atlantic Ocean. Nor'easters of 1932, 1947, 1962, and 1973 caused extensive erosion along the southeastern US coastline, while Hurricane Dora (1964), the "first hurricane on record to move inland from the Atlantic," washed away dunes and lowered beaches in the Cumberland Island area by as much as 1.5 m [5 ft].

Conventional littoral drift calculations were carried out by the COE and the University of Florida. Net littoral drift in the vicinity of St. Marys Entrance adjacent to Cumberland Island is reported to be between 182,000 m^3 (238,000 yd^3) and 382,000 m^3 (500,000 yd^3) to the south (USACE, Parchure, 1982). Walton and the COE (as cited by Dean & O'Brien, 1987) have estimated the net southward drift to be between 153,000 m^3 (200,000 yd^3) and 420,500 m^3 (550,000 yd^3) annually. However sediment budget calculations reported by Parchure, (1982) do not correspond to the net southward littoral drift, but show a long term movement of sand offshore and to the north.

6.2 St. Marys Entrance

6.21 Inlet Modifications

According to Parchure (1982), St. Marys Entrance has been navigable throughout its recorded history, beginning with the establishment of the harbor town of St. Fernandina in 1567. Because the main channel entrance had migrated and inlet shoals had become a hazard to navigation, in 1880 Congress approved the construction of rubble-mound jetties at St. Marys Entrance in order to stabilize the location of the inlet and the channel.

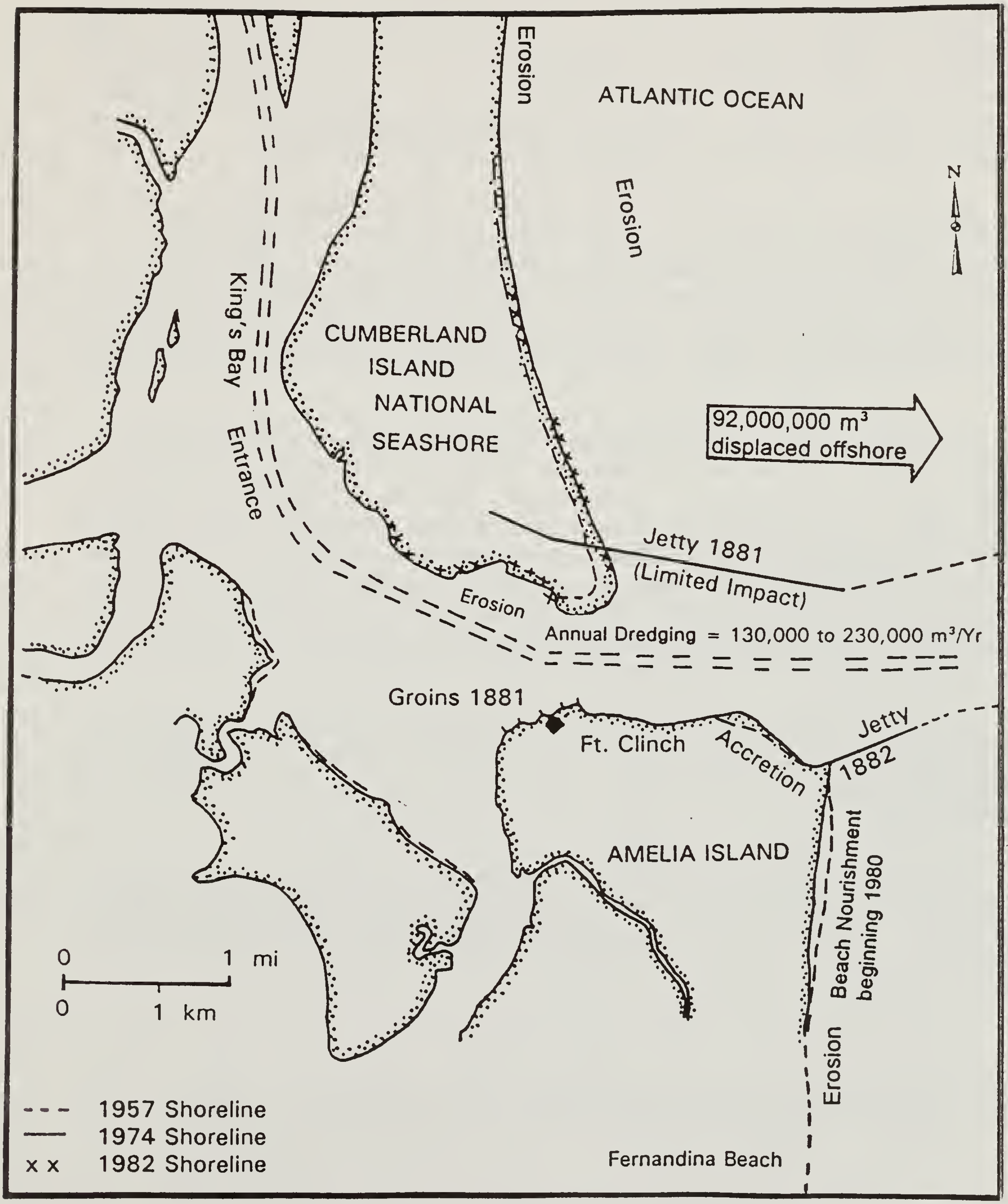

Fig. 8. St. Marys Inlet, Cumberland Island National Seashore, Georgia.

Construction of the jetties began in 1881; however, rapid shoreline recession on the northern shore of Amelia Island occurred immediately endangering Fort Clinch. In 1883, a series of spur groins were built to protect the fort. The jetties were completed in 1905 and were extended to their present length in 1927. The northern jetty is 5.8 km (3.6 mi) long with a crest elevation of 2.1 m (6.9 ft) MLW and the south jetty is 3.4 km (2.11 mi) long with a crest elevation of 1.8 m (6 ft) MLW. The low profile of the jetties combined with the large stone used in their construction, have rendered the jetties relatively permeable to sand. As a consequence, extensive shoals have developed on the inlet sides of the jetties.

The original entrance channel was 5.8 m (19 ft) deep and 1,190 m (3,900 ft) wide. Following completion in 1905, repair work on the jetties and channels continued (with interruptions because of lack of funding). This helped mitigate shoaling problems, and prevented the natural opening of a second channel adjacent to the northern jetty. From 1905 to 1937, extensive dredging and construction work were required to confine the tidal flow to a single channel within the two jetties. Work included repair of a breech in the northern jetty and elevation of the crest of the northern and southern jetties.

From 1940 to 1979, numerous dredging and realignment projects were undertaken to increase the channel depth and improve navigation for commercial and military vessels. The entrance channel was maintained at a depth of 12.2 m (40 ft) and a width of 122 m (400 ft) (Sargent, 1988). The channel extended 22 km (13.7 mi) to the 9.8-m (32-ft) contour and 13 km (8.1 mi) to the King's Bay Submarine Base. Between 1985 and 1989, the Navy increased the depth of the channel to 15.5 m (51 ft) and the channel width to 152 m (500 ft) for a 35.4 km (22 mi) stretch of navigation channel to accommodate the Trident-class submarines that were stationed at King's Bay Terminal. This required the removal of approximately 26,800,000 m^3 (35,000,000 yd^3) of dredged material from the channel.

In order to reduce shoaling in the inlet channel, the COE (USACE JD, 1988) reported the award of a contract to "sand-tighten" the landward 457 m (1,500 ft) of the southern jetty by removing the top section of the existing jetty, and replacing it with precast concrete sections and 8-ton armor stone.

Maintenance dredging of St. Marys Inlet has increased over time in order to maintain the increased channel cross-sections (Table 1). Unless otherwise noted, dredged materials were placed offshore. From 1955 to 1990, approximately 430,500 m^3 (563,100 yd^3) were dredged annually from the inlet. Small quantities were also placed on Cumberland Island north of Raccoon Keys and at the south end of the island.

Table 1 Summary of maintenance dredging volumes, St. Marys Inlet, 1903 to 1990

Dates	Sediment quantity	Source of information
1903 to 1955:	1,307,000 m^3 (1,709,000 yd^3)	(Parchure, 1982)
1903 to 1985:	9,863,000 m^3(12,900,000 yd^3)	(Dean, 1987)
1955 to 1990:	15,067,000 m^3 (19,707,000 yd^3)	(COE, Jacksonville District)

6.22 Inlet Effects:

Olsen (1977) compared pre- and post-jetty construction hydrographic surveys at St. Marys Inlet to make an accretion-erosion sediment map. Parchure (1982) citing Olsen (1977) and Nash (1977) pointed out that a major effect of the jetties is the offshore deposition of sediment in the form of shoals seaward of the jetties (lost from the active littoral drift system). He estimated that, during the 100 year period of measurement since modification to St. Marys channel, more than 94,040,000 m^3 (123,000,000 yd^3) of sand have been displaced from Cumberland and Amelia Island nearshore areas to the offshore shoals. Dean (1987) estimated that between 1857 and 1975, 9,328,000 m^3 (12,200,000 yd^3) of sediment had eroded over a 7.6 km length of shoreline updrift of the 1.52 km sand fillet at the northern jetty on Cumberland Island. By contrast, Parchure estimated (citing Olson, 1977) that each jetty had accumulated only 7,646,000 m^3 (10,000,000 yd^3) [in sand fillets] during approximately the same period (1880 to 1982). Griffin and Henry (1984) using historical maps showed that the north end of Amelia Island and the south end of Cumberland Island shifted seaward 1463 m and 786 m respectively from 1857 to 1982. Parchure (1982) concluded that sand bypassing and net littoral drift appear to be unsatisfactory for explaining sediment transport processes at St. Marys Inlet. The jetties have caused "...a net offshore deposition and a net loss from the nearshore littoral system and consequential shoreline erosion."

In 1986, the Kings Bay Environmental Monitoring Program was developed by the U.S. Departments of Interior and Navy. The five year project, begun in 1988 and funded by the Navy, was designed to evaluate the potential effects of channel deepening (for the Trident Submarines) on the natural resources of Cumberland Island and vicinity (Cofer-Shabica, 1991). The physical monitoring was conducted by the COE, the results of which are just now being published. In a review of inlet morphology and post-construction evolution of four ebb-tide dominated inlets including Cumberland Island, Pope (1991) noted that the extensive (84 km^2, 32 mi^2) ebb-delta shoal complex at St. Marys Inlet collapsed as a result of channel stabilization (Fig. 9). As ebb-delta deposition is diverted offshore by the jetties, sediments in the existing ebb-delta are scoured by waves and transported toward the beach. A result is steepening of the offshore profile on both updrift and downdrift sides of the inlet as sediments are carried downdrift. "It is the loss of this ebb-delta platform which can influence the sediment budget and wave conditions over a broader section of the coast" (Pope, 1991). In addition to confirming previous research on the ebb delta, Pope concluded that shoreline changes in an ebb-tide dominated inlet may not be the most sensitive short-term effect.

To mitigate erosional problems on the developed shore of Amelia Island a beach nourishment program was started. According to a COE Memorandum of Understanding (Dean, 1987), the dredged material of all channel maintenance dredging were to be placed upon Amelia Island to maintain stability of the shoreline. Dean (1987) reported that, since nourishment of Amelia Island beaches had begun in 1985 with 306,000 m^3 (400,000 yd^3), there had been no further offshore placement of dredged materials outside of the littoral drift system. He added that, from 1903 to 1985, 9,557,000 m^3 (12,500,000 yd^3) were "disposed at sea." By 1991, approximately 800,000 m^3 of dredged channel material had been pumped between the dune line and MHW along the northern and central sections of Amelia Island (Gorman, 1991).

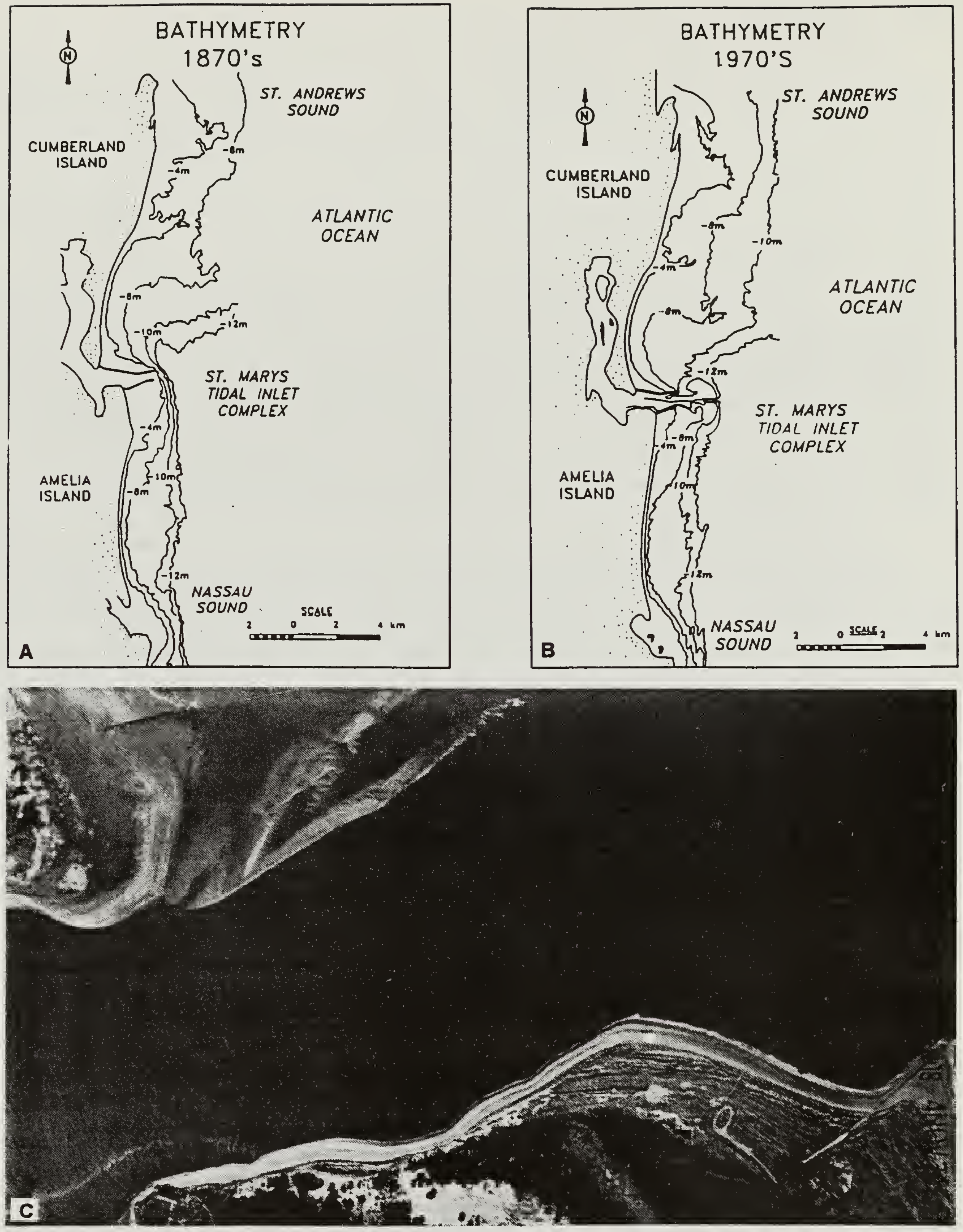

Fig. 9. Comparison of (a) pre-project [1870] and (b) evolved [1970] bathymetry, St. Marys Inlet, Georgia [Pope, 1991]. (c) Aerial Photo, 4 November 1971.

6.23 Summary and Recommendations

The open ocean coast of Cumberland Island is generally accreting. The open ocean coast of Amelia Island actively eroding, in part due to St. Marys Inlet stabilization. The jetties at St. Marys Inlet has caused the deposition of ebb-tide sediments to be moved farther offshore. Also, the ebb-delta lobe has collapsed resulting in a steepening in the nearshore bathymetry. Shoreline erosion has been noted on either side of the inlet and on the seaward sides of the islands (in some locations, 13.7 km [8.5 mi] north on Cumberland Island and 12 km [7.5 mi] south on Amelia Island). To mitigate the erosion on Amelia Island groins were constructed at the north end of the island, and recently-dredged sediments were used to nourish Amelia Island beaches.

1) The study of the ebb-delta and surrounding seabed bathymetry must continue to provide data for long-term management of St. Marys Inlet and Cumberland Island NS.

2) Losses of material to updrift and downdrift beaches should be mitigated with beach nourishment. However, the balance of material from dredging should be placed in areas to maintain the nearshore ebb-delta shoals, as these are a primary defense for Cumberland and Amelia Islands from storm waves. "The adaptation of maintenance and disposal practices are probably of more long-term value than a traditional "quick fix" to the adjoining shore [i.e. beachfill]" (Pope, 1991).

3) Accurate mapping is necessary to document the evolution of the ebb-delta complex and to determine whether regression of Cumberland Island shorelines is progressing. This is particularly the case along the previously erosional northern and central areas. If it is, mitigation by beach nourishment from dredged sediments is clearly appropriate.

4) The King's Bay Environmental Monitoring Program should continue. The current coastal monitoring project (authorized in the Military Construction Appropriation Act of 1988) may not include GPS/GIS mapping of the area covering the northern and north-central regressive shorelines of Cumberland Island. If it doesn't a comparative study of the shoreline change rates from these shores should be proposed and authorized.

5) GPS/GIS data, providing total coverage of Cumberland Island shoreline features will establish the best baseline of data to assist in the making of change-rate determinations. As part of the Historical, Monitoring, and Shoreline Evolution Substudies (of the King's Bay Environmental Monitoring Program), these and related data are to be incorporated into a GIS park-specific Cumberland Island National Seashore Resource Management Database.

7.0 Castillo de San Marcos National Monument

and

Fort Matanzas National Monument

7.1 General Introduction

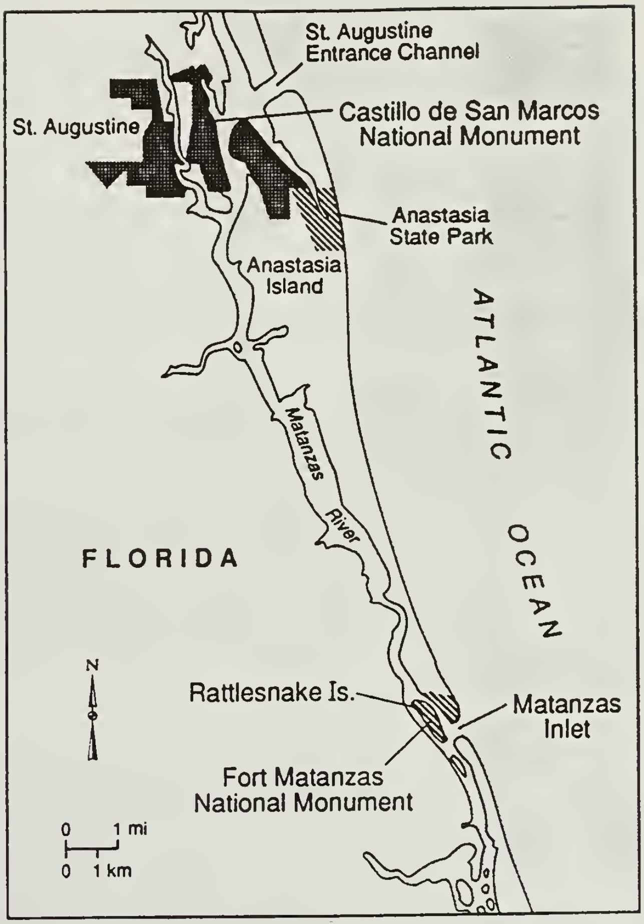

Fig. 10. Castillo de San Marcos and Fort Matanzas National Monuments, Florida.

Castillo de San Marcos fortress is located on the western shore of the St. Augustine Inlet, Florida. It was built in 1669 to control river approaches to the town of St. Augustine. After the end of Spanish and Mexican control of the Florida region in 1821, Castillo de San Marcos was renamed Fort Marion in 1825. The site was proclaimed a national monument in 1924, given its original name, and in 1935 became a unit of the National Park Service (Fig. 10).

In 1924, Fort Matanzas was also proclaimed a national monument. The fort was constructed by the Spanish in 1742, approximately 22.5 km (14 mi) south of St. Augustine to guard the Matanzas River approach to St. Augustine. At that time, Fort Matanzas was located on a small island near the mouth of Matanzas Inlet. Accessible only by boat or ferry, the structure stands today in a very different environment located more than 1 km north of Matanzas Inlet. This dramatic change has been due to natural southerly inlet migration as well as engineered channel cutting, dredging, filling, armoring, and maintenance of the Intracoastal Waterway.

Although both park units are located behind barrier islands, Castillo de San Marcos and Fort Matanzas are each impacted differently by coastal processes and inlet and channel modification. St. Augustine Inlet has been extensively modified by the construction of jetties to relocate, stabilize, and maintain a channel for commercial and military vessels. Matanzas Inlet is not stabilized with jetties, however the south shoulder of the inlet has been armored to protect the Highway A1A bridge.

7.2 St. Augustine Inlet

7.21 Introduction

Historically St. Augustine Inlet has served as a junction for the lower reaches of the Tolomato, Matanzas, and San Sabastian Rivers and as an entrance to the ocean. Castillo de San Marcos is located in a sheltered location behind the barrier islands of Vilano Beach, Anastasia Island, and [now] Conch Island (Fig. 11).

Historic maps and data suggest that the location of St. Augustine Inlet (now Conch Island) has remained approximately the same since mapping began in 1586. This history is in sharp contrast to the frequent opening, closing, and migration of inlets along the Outer Banks. Prior to relocation and stabilization in 1940, St. Augustine Inlet had several primary channels which often shoaled or changed location.

Littoral drift at St. Augustine Inlet was reported by Walton, (1976) and the COE (USACE JD, 1990) at 290,500 m^3 (380,000 yd^3) and 177,377 m^3 (232,000 yd^3) respectively to the south. Dean & O'Brien (1987) reported ebb shoal growth from 58,641,353 m^3 (76,700,000 yd^3) in 1924 to 84,407,000 m^3 (110,400,000 yd^3) in 1979. They further reported a substantially smaller flood shoal volume of 535,000 m^3 (700,000 yd^3) in 1970. More recently, according to the COE (USACE JD, 1990), a result of the inlet stabilization and channel dredging was that the ebb shoal stores 84,101,000 m^3 of sediment (110,000,000 yd^3) outside of the littoral drift system.

A COE (USACE JD, 1990) review of shoreline change rates for the period 1858 to 1986 indicate that the Atlantic shore in the St. Augustine area has been stable with periods of accretion balanced by periods of erosion. They calculate a net shore accretion for the area of 0.21 m/y (0.7 ft/y). This supports a Dean and Obrien (1987) report of accretion of 1,147,000 m^3 (1,500,000 yd^3) 4 km north of St. Augustine Inlet between 1924 and 1976 and accretion of 5,581,000 m^3 (7,300,000 yd^3) 9 km south of the inlet. However, they reported severe erosion beginning 6.4 km (4 mi) south of the inlet.

The COE (USACE JD, 1990) reported that the "Florida coastline is affected more by hurricanes than any other Atlantic or Gulf State, and has received 36% of all hurricane making landfall;" however, the COE also reported that the "storm tracks of most hurricanes either follow a path parallel to the coast or pass west to east across the peninsula." With the exception of Hurricane Dora (1964), the COE concluded that "the devastating effects of storm surge accompanying a direct land falling hurricane have been minimal along this part of the coast." Nor'east storms, notably the 1962, 1963, 1974, and 1984 storms, have had a greater erosional impact on the coastal areas adjacent to St. Augustine Inlet (USACE. 1990).

7.22 Inlet Modifications

Shoaling within the historic St. Augustine Inlet (Fig. 11, 1861 shoreline) prompted the federally sponsored relocation of the primary inlet channel to the north through the Vilano Beach barrier in the 1940s. The channel was dredged in 1940 and the following year, a

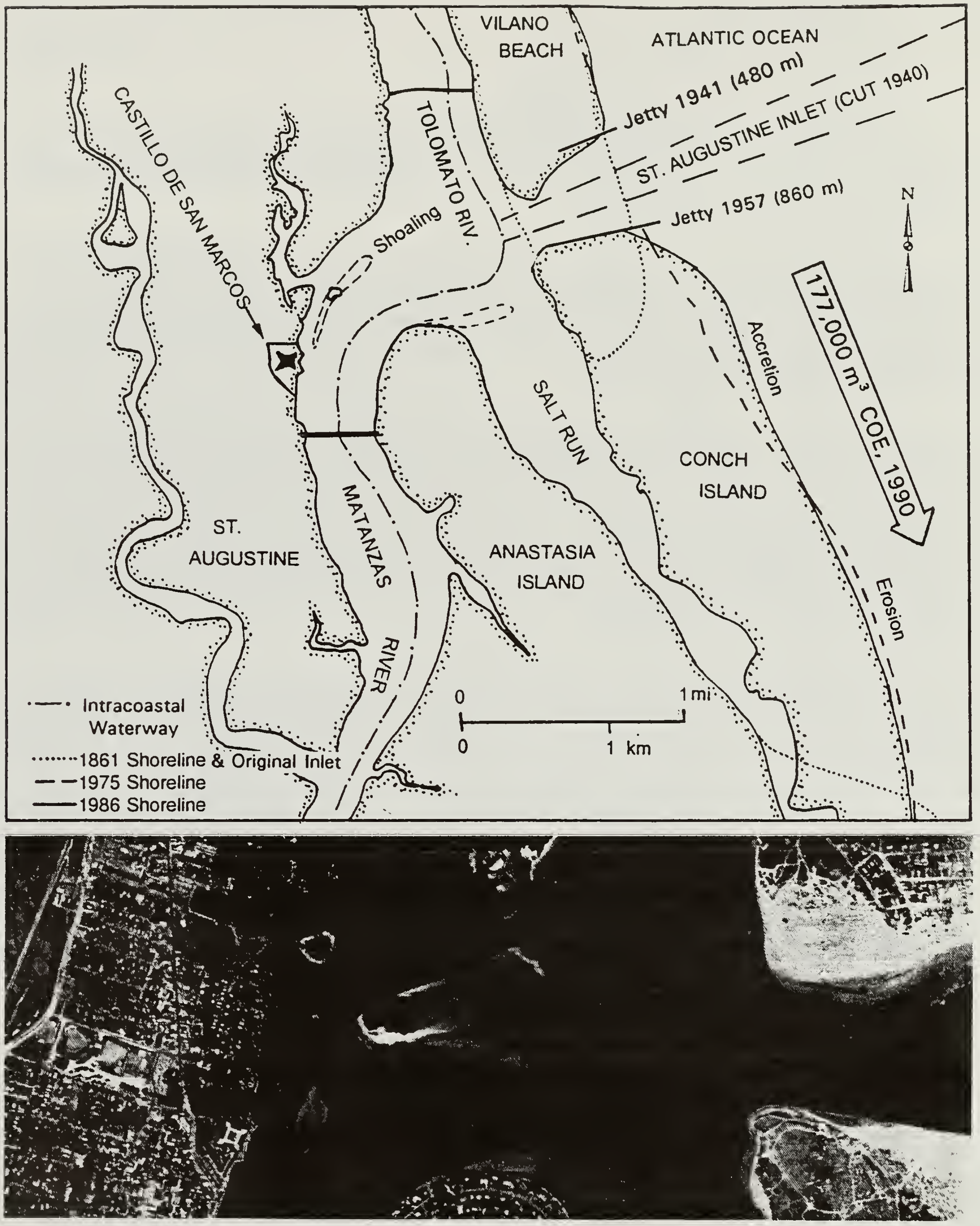

Fig. 11. St Augustine Inlet, Castillo de San Marcos National Monument, Florida. Aerial Photo 15 March 1979.

481.6-m (1,580-ft) jetty was constructed on the north side of the new inlet. Following repairs to the structure in 1942 and 1943, a 861-m (2,825-ft) southern jetty was constructed in 1957.

As the majority of tidal flow was diverted from the original inlet, this area shoaled rapidly with the resultant growth of Conch Island. From 1956 to 1975 Conch Island continued its growth and finally connected to Anastasia Island. This barrier island shoreline is now a part of Anastasia State Park.

The COE (USACE ND, 1989) reported no repair work from construction to 1985 and proper functioning of the system. Dean & O'Brien (1987) reported that between 1940 and 1985 1,224,000 m^3 (1,600,000 yd^3) of material had been dredged and that all but 91,747 m^3 (120,000 yd^3) had been placed on St. Augustine Beach or within the littoral zone. According to the COE (USACE JD, 1990), very little dredging has taken place since the 1970s, and that the last dredging occurred in 1986. That dredging program removed 92,700 m^3 (121,260 yd^3) of sediment from the system and placed it in nearshore waters opposite St. Augustine Beach. The report stated that since 1977 all deposits have been in this "beach nourishment" area.

7.23 Inlet Effects

The Castillo de San Marcos National Monument lies in a sheltered environment. However, because of altered shoreline and inlet reconfiguration, the monument is less protected from nor'east storms than it was prior to relocation of the inlet channel in 1940.

The monument is also affected by the accretion of sediments that resulted from modifications to the St. Augustine Inlet. Following construction of the groin and jetty in the 1940s, aerial photos taken in 1947, 1956, 1971, and 1979 showed flood tidal accretion along the northern shore of the inlet, growth and stabilization of the sand bar migrating towards the front of the monument, and movement of the channel back towards its reported historical location along the western shore and northern lobe of Anastasia Island.

Erosion continues to take place downdrift from the inlet and in the Anastasia Beach area. The COE (USACE JD, 1990) estimated that 50% of the erosion is attributable to St. Augustine Inlet maintenance. Dean and O'Brien (1987) reported "that the littoral transport does not appear to be passing around this entrance." The COE (USACE JD, 1990) reported that along the coasts of Anastasia State Park and southeastern coasts of Anastasia Island "little if any dry beach exists along this area at high tide and much of the low tide beach is strewn with the scattered debris and broken asphalt of old FL Highway A1A" [which was destroyed during the storm surges of Thanksgiving Day, 1984]. The COE also noted that "with the relocation of the inlet, the support mechanism for the cape development has been removed." This has left a distinctive bulge in the shoreline causing wave focusing and sediment transport away from the area. The COE concluded that the relocation of the federal navigation project has had a negative impact on the beaches to the south. In this report, the COE evaluated proposals for beach nourishment of a 4 km (2.5 mi) section of shoreline at Anastasia State Park and St. Augustine Beach 4.8 km (3 mi) south of St. Augustine Inlet. Although the inlet was considered responsible for half of the erosion in that area, the project was not justified economically. Dredge materials continue to be deposited off St. Augustine Beach in waters shallower than 4.3 m (14 ft).

7.24 Summary and Recommendations:

At this time Castillo de San Marcos remains in a generally stable, low-energy environment. However, inlet relocation has made the monument more vulnerable to nor'easter storms. Previous dredging in the inlet has not had a negative impact on the monument site or the seawall that protects the monument.

1) If the sandbar continues to prograde in the channel to the east of the monument, marshes may develop, and future dredging of this bar may be useful to help maintain the functions and values of the monument.

2) The seawall protecting the fort should be periodically checked for undercutting and should be repaired as necessary.

3) Although not directly impacting NPS property, all St. Augustine dredged materials should be bypassed downdrift. As has been documented in studies on the effects of the modifications at St. Augustine Inlet, erosional impacts can occur downdrift when dredged sands are not kept in the littoral drift system.

7.3 Fort Matanzas National Monument

7.31 Introduction

Fort Matanzas is located on Rattlesnake Island, approximately 22.5 km (14 mi) south of St. Augustine and 2.4 km (1.5 mi) north of Matanzas Inlet (Fig. 12). Fort Matanzas National Monument lies east of the Intracoastal Waterway and includes Rattlesnake Island and the south end of Anastasia Island. The site around the fort has been extensively modified in its 250 year history and originally occupied a 0.4-hectare (1-acre) site.

Translated from Spanish, Matanzas means "slaughters." The name was given to the inlet after 245 French soldiers were executed by the Spanish in 1565 following an unsuccessful attack by French forces. The French fleet was later scattered by a hurricane, effectively bring a close to the bloody conflict. In order to provide a permanent defense against further invasion, the Spanish built a series of watch towers and forts to guard Matanzas Inlet beginning in 1569. In 1742 the construction of a stone fort was completed on the site. This is the monument which stands today.

The United States gained control of the area in 1821, and at various times between 1834 to 1872 the fort, the inlet, and the area around it were surveyed, and in 1883 the inlet and marshlands to the west became part of the first intracoastal canal project. Construction of the canal began in 1885 and was completed by the Florida East Coast Canal Company in 1912. However, following several years of deterioration and lack of canal maintenance, concrete retaining walls were built around the north, east and south sides of the fort by the War Department in 1916 (Mehta & Jones, 1977). After the declaration of the site as a national monument in 1924, a sequence of maintenance and improvement measures were undertaken in the area which affected the inlet, the monument, the island park property, and the canal (now the Intracoastal Waterway).

Following large-scale alteration of the area due to relocation of the Intracoastal Waterway in the 1930s, the Matanzas Monument property grew and now comprises the fort site and 120.6 hectares (298 acres) of Park Service property located on Rattlesnake Island and Anastasia Island. Florida Highway A1A runs down the length of Anastasia Island, crosses NPS property, and bridges the Matanzas Inlet to the town of Summer Haven.

Historically, the dominant geographic changes in this area have been the southward-progradation of Anastasia Island, and the southward-migration of the mouth of Matanzas Inlet. According to Mehta and Jones (1977), the southern end of Anastasia Island grew southward approximately 0.5 km (0.3 mi) between 1765 and 1882, and grew again by approximately the same amount between 1882 and 1923. More recent and frequent measurements show that southward migration has continued. The distance from the fort to the mouth of the inlet is now 2.4 km (1.5 mi).

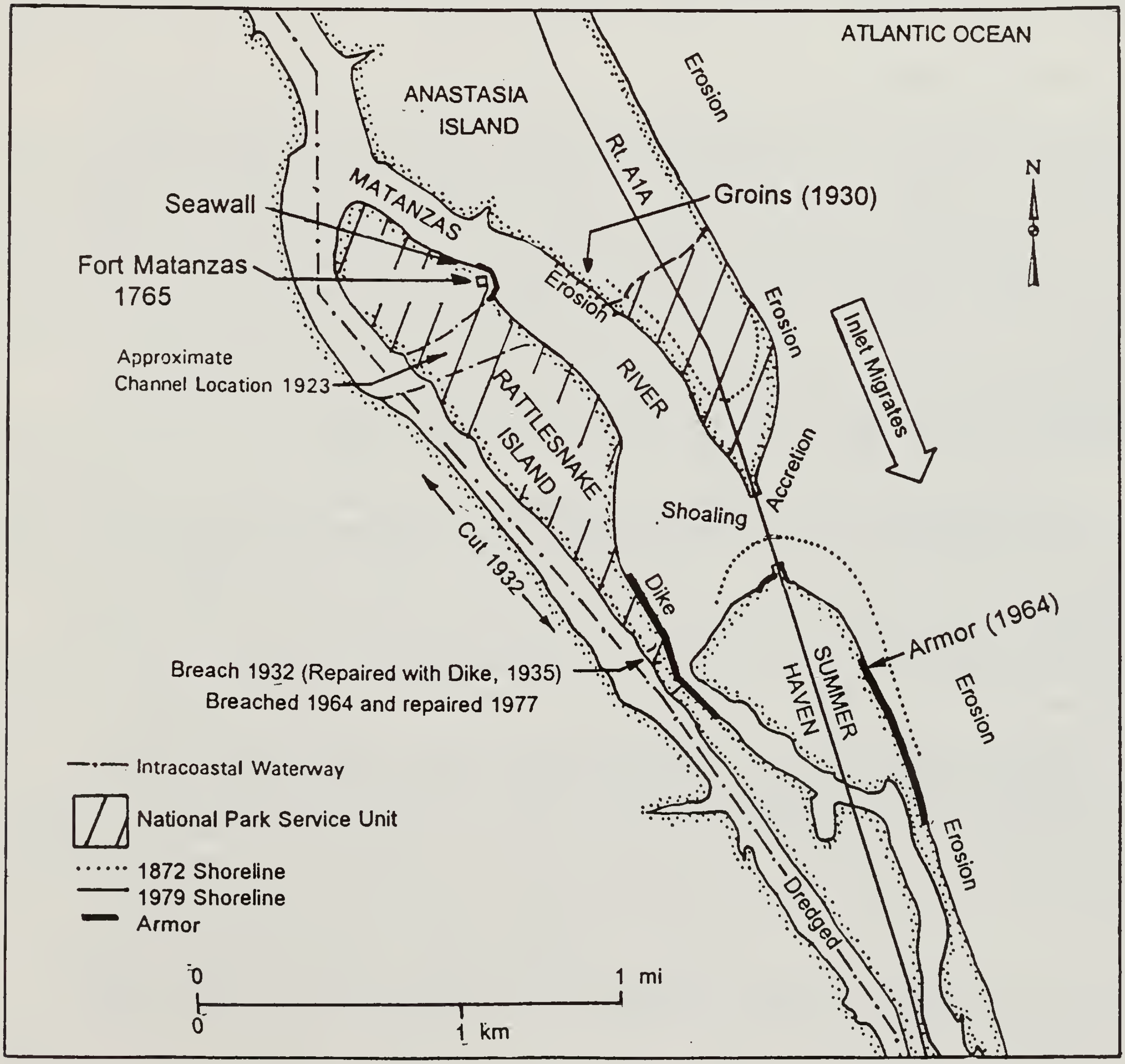

Fig. 12. Matanzas Inlet, Fort Matanzas National Monument, Florida.

Storms and hurricanes have had well-documented effects upon the barrier islands in Matanzas Inlet area. The impact of nor'easter storms accounts for most of the erosion recorded since 1830. In 1947 and 1956, for example, nor'easter storms created severe erosion, dropping the beach profile as much as 1 m (3.3 ft) in vertical direction. Mehta and Jones (1977) describe erosion averaging between 1.8 m (6 ft) and 5 m (16.4 ft) per year along the southern coast of Anastasia Island from 1860 and 1972.

Net littoral drift has been calculated at 222,000 m^3 (290,000 yd^3) to 336,000 m^3 (440,000 yd^3) to the south (Walton, 1976 and USAE, respectively; after Dean & O'Brien, 1987). Dean and O'Brien (1987) reported that there has been severe erosion immediately south of Matanzas Inlet "undoubtedly due to the storage of large quantities of beach quality sand as an emergent flood tidal shoal." According to these authors, 306,000 m^3 (400,000 yd^3) of sediment were "stored" within the inlet, and increases between 1964 and 1978 of 1,453.000 m^3 (1,900,000 yd^3) within the offshore ebb shoal volume have brought the total offshore volume to 4,817,000 m^3 (6,300,000 yd^3).

7.32 Inlet Modifications

Matanzas Inlet is the "last unimproved inlet on the eastern coast of Florida (Mehta & Jones, 1977). "It is characterized by a significant offshore bar that is very transitory in nature, and the presence of appreciable inner shoals...." By "unimproved," it is meant that no Federal project has authorized the construction of jetties or groins to maintain the position of the inlet or maintain the depth of the channel for commercial or military purposes; however, the inlet does contain piers and abutments for the highway bridge. Further, the Matanzas River has been separated from the Intracoastal Waterway with sheet pile dikes and stone revetments; the monument site has been protected with retaining walls, seawalls and groins; the shoreline of Anastasia Island across from the monument has been stabilized with groins; and sections of the northern end and eastern shoreline of Summer Haven have been armored.

In 1916 erosion at the fort necessitated the construction of a retaining wall, and again in 1935 with three groins and a seawall. During the same period 11 groins were constructed on the opposite shore of Anastasia Island. Dredging first occurred in 1930 in the Matanzas Inlet. Approximately 44,800 m^3 (58,640 y^3) of sediment were removed from shoals on the north and south sides of the inlet (USACE JD, 1930). By 1932, the Intracoastal Waterway bypass channel (known as the "Matanzas Relocation Cut") had been completed and that changed the configuration of Rattlesnake Island. Following this, river traffic was rerouted west of the national monument. As part of the relocation project a 2,880 m (9,450 ft) sheetpile dike and stone revetment system was built to close a breach opened in 1932 between the Matanzas River and the Intracoastal Waterway. Beginning in the 1940s periodic dredging took place in the Matanzas Relocation Cut and within the Intracoastal Waterway to deepen the channels and remove "critical shoals." In 1956 a new bridge was built across Matanzas Inlet and a concrete and sheet pile seawall was constructed to protect the bridge. In 1962 a nor'easter eroded the southern shore of the Matanzas Inlet, damaged FL Highway A1A, and threatened the bridge. In 1964 Hurricane Dora struck the St. Johns County shoreline and the storm surge within the inlet broke a channel through the dike at the southern end of Rattlesnake Island into the Intracoastal Waterway south of the fort.

Mehta and Jones (1977) reported that by 1972 the breakthrough at Rattlesnake Island had opened to 76.8 m (250 ft). In 1973 and 1974 the water depth at the breakthrough was measured by the COE at -9.1 m (-30 ft). To repair the break, a 94.5 m (310 ft) sheetpile dike was approved and construction began in 1976 to once again separate the Matanzas Inlet, Matanzas River, and the Intracoastal Waterway.

In 1973 of 86,000 m^3 (112,447 yd^3) of sediment were dredged at the confluence of the Intracoastal Waterway and the northern arm of the Matanzas River (Mehta & Jones, 1977). Dredged materials were to be placed on Summer Haven beaches south of the inlet.

7.33 Inlet Effects

Dredging and channelization projects in the Intracoastal Waterway have been the primary human factors affecting the Fort Matanzas National Monument inland shores of Rattlesnake Island and Anastasia Island. Anastasia Island lies on the updrift side of Matanzas Inlet and is thus minimally affected by inlet dredging or armoring of the bridge abutments.

Presently, the Highway A1A bridge abutments interfere with the tendency for the Matanzas Inlet to migrate southward. The migration of the inlet may also be partially controlled by a strong tidal prism caused by dredging north of Rattlesnake Island at the confluence of the Matanzas River and the Intracoastal Waterway. Mehta and Jones (1977) reported the tidal prism prior to the 1964 breakthrough as 95% within Matanzas River adjacent to the monument, and 5% in the southern arm of the Matanzas River. By contrast, after the breakthrough they reported only 19% of tidal prism could be measured in front of the fort, and 81% occurred in the breakthrough and the Intracoastal Waterway.

Shoreline changes mapped between 1765 to 1972, have shown that Matanzas Inlet has historically been active. Migration of the inlet, shoaling, and erosion may still occur as a result of frequent and intense nor'easters. Shoreline changes include the progradation of the southern end of Anastasia Island into the inlet, the corresponding accretion of shoal material into Rattlesnake Island, and a downdrift beach and shoreline regression of the southern shore of Matanzas Inlet at the northern end of Summer Haven.

Although monument property has increased on Anastasia Island as a result of prograding of the island and migration of Matanzas Inlet, erosion has occurred on shorelines updrift and downdrift of the inlet.

At the time of this writing, we do not known if further inlet modification has been proposed or authorized, or if any routine channel dredging or sand bypassing is occurring at Matanzas Inlet in connection with maintenance of the Intracoastal Waterway or the channel in the Matanzas River.

7.34 Summary and Recommendations:

Fort Matanzas National Monument has over a 100 year history of engineered modifications to its boundaries beginning with the construction of the Florida East Coast Canal (later Intracoastal Waterway). Retaining walls, groins, a 2,880 m dike and revetment were constructed to protect the fort and monument lands, and maintain the Intracoastal Waterway.

The Fort Matanzas monument site appears to be relatively stable with respect to erosion. However, the coastal area of the park on Anastasia Island adjacent to Matanzas Inlet has been steadily accreting on the southern tip and eroding along the ocean coast. Further offshore erosion has caused steepening in the offshore profile.

1) If dredging is necessary to remove shoals from Matanzas Inlet, the dredged sediments should be placed within the littoral drift system. Dean (1987) recommended sand be bypassed from the flood shoal to Summer Haven beaches.

2) Sediments dredged to maintain St. Augustine Inlet to the north must be placed within the littoral drift system to minimize erosion to the offshore profile and the ocean shores of Anastasia Island.

3) Armored sections of shore on national monument property should be maintained and unprotected sections should be monitored for damage relating to waterway or inlet maintenance.

4) National monument property on Anastasia Island must be accurately mapped to measure shoreline changes by GPS/GIS technologies and the data gathered along with data from monitoring of shore protection armor should be incorporated into a park-specific Resource Management Database.

8.0 Canaveral National Seashore and Merritt Island National Wildlife Refuge

8.1 Introduction

Approximately 16 km (10 mi) south of New Smyrna Beach, Fl, and extending another 37 km (23 mi) further south along the Atlantic coast of Florida, runs a narrow stretch of barrier beach protecting two shallow, and brackish lagoons. This area encompasses both the Canaveral National Seashore (NS) and the Merritt Island National Wildlife Refuge (NWR). The area adjoins the Kennedy Space Center and the Cape Canaveral Air Force Station. The beaches can be reached by vehicle through New Smyrna Beach at the northern end and through Titusville, the southern access point. The lagoons are accessible to boats via the Intracoastal Waterway (Fig. 13).

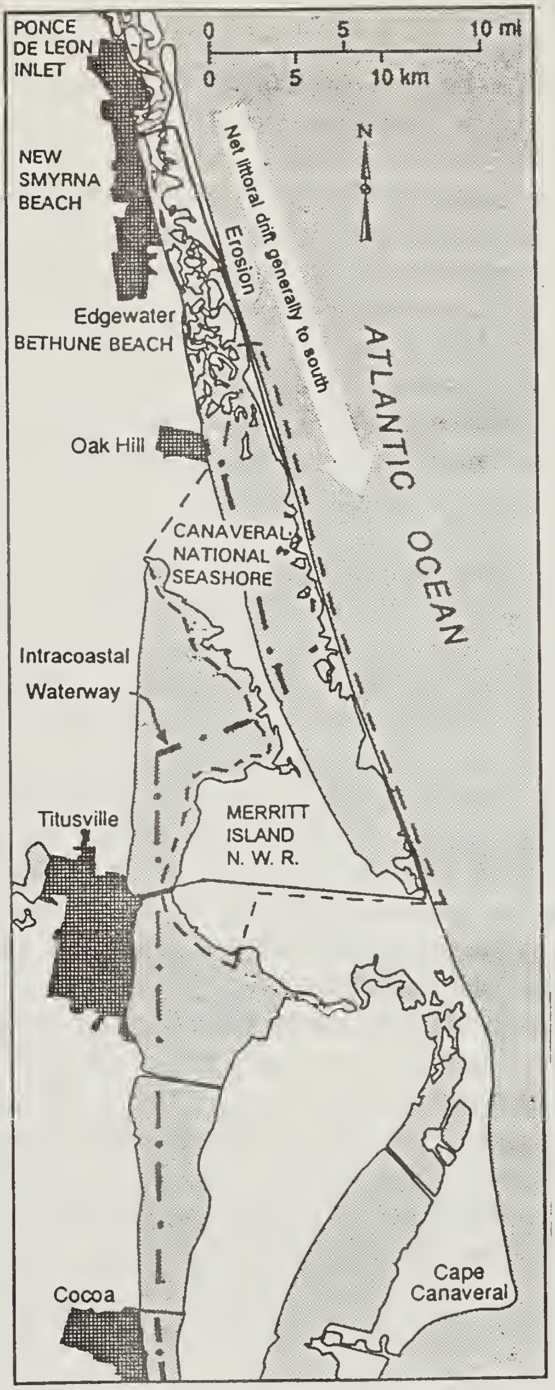

Fig. 13. Canaveral National Seashore and Merritt Island National Wildlife Refuge, Florida.

The literature provided by the Canaveral NS and the Merritt Island NWR provides an insight into the character of these two units. Seashore visitors are advised to plan their visits carefully, as "the right combination of high tides and rough surf can leave hikers with little or no beach on which to walk." Visitors to the Merritt Island NWR, which is protected by the barrier beaches, are advised that "at Turtle Mound, a short self-guiding trail leads to the top of a prehistoric Indian shell-midden."

The Canaveral National Seashore lies 16 km (10 mi) south of the federally maintained Ponce de Leon Inlet at New Smyrna Beach. The stabilization and dredging of the inlet could in theory accelerate erosion at the national seashore and will be discussed here.

8.2 Ponce de Leon Inlet

Ponce De Leon Inlet at New Smyrna Beach, FL is located approximately 104 km (65 mi) south of St. Augustine and 92 km (57 mi) north of Canaveral Harbor, FL. The inlet provides access and connections to the Halifax River to the north, the Indian River to the south, and the Intracoastal Waterway to the west. This very dynamic "natural" inlet is a vital part of the residential and commercial activity of the area, thereby satisfying broad and varied waterway demands. However, prior to inlet improvement in 1968, and stabilization in 1972, Ponce de Leon Inlet was known as a "Killer Inlet" because "scores of ships [were] wrecked on the shifting shoals and bars" (Mehta & Jones, 1978).

Other inlets were periodically opened through the barrier islands in the area south of Ponce de Leon Inlet. The most recent of these inlets closed at approximately 1,450 BP and existed near what is known today as Turtle Mound" (Mehta & Brooks, 1973).

In 1513, the Spanish adventurer Ponce de Leon made landfall north of the inlet, and proceeded south along the Atlantic coast to a nearby river that some think was the Halifax River (Davies, 1975). He called the river "Rio de la Cruz," possibly because of the T-shaped junction of the inlet with the rivers. Historic documents designated the inlet as "Mosquito Inlet" until it was renamed Ponce de Leon Inlet in 1926. From 1573 until 1821 the inlet served the military and commercial needs of the Spanish and English. After the U.S. acquired Florida by treaty in 1821, settlement increased in the area around Ponce de Leon Inlet.

According to shoreline charts from 1851, 1874, 1925, and 1934, Ponce de Leon Inlet has historically been a dynamic inlet, with broad changes in the width of the inlet, in the configuration of adjacent shorelines, and in the location of ebb and flood tidal shoals. Of particular interest are large variations in the littoral drift. Dean and O'Brien (1987) reported strong transport reversals occurring during summer months in the inlet area. Generally, net littoral drift transport is to the south. Mehta and Jones (1978) estimated the southerly littoral drift past the inlet to be 535,200 m^3 (700,000 yd^3), with the inlet trapping only 38,200 m^3 (50,000 yd^3) of sediment per year. The COE (USACE JD,1983) reported an average net southerly littoral transport volume of 80,300 m^3 (105,000 yd^3) for the period 1969 to 1975 and a net northerly transport of 99,390 m^3 (130,000 yd^3) for 1976. More recently, Taylor (1990) reported a net littoral drift of 102,450 m^3 (134,000 yd^3) to the south.

8.21 Inlet Modification

The Florida East Coast Canal which would later become a key section of the Intracoastal Waterway was completed in 1912. Between 1932 and 1933 a cut was made west of Ponce de Leon Inlet to create access to the waterway, and approximately 714,000 m^3 (934,000 yd^3) of sediment were dredged from the cut and the inlet (Jones and Mehta, 1978). This period of Intracoastal Waterway construction started a series of increasingly large-scale modifications to the inlet and the channel.

Beginning in 1943, an active program of dredging began with the cutting of a channel through the Ponce de Leon Inlet and across the seaward bar by the COE (Jones and Mehta, 1978). Approximately 657,500 m^3 (860,000 yd^3) were dredged; however, within a year rapid shoaling had "severely restricted the use of the inlet."

The COE (USACE JD, 1962) reported that erosion predominated over a 3.2-km (2-mi) stretch of shore north of the inlet and that both accretion and erosion had taken place 6.4 km (4 mi) south of the inlet, with "shore line recession accompanied by accretion of the offshore part of the profile."

A series of channel maintenance programs continued through 1965, when, because of continued unstable conditions and high cost of maintenance, the COE was authorized to stabilize the inlet with jetties. The design called for a weir and sand impoundment basin on the north side of the inlet. Construction began on the jetty system in 1968 and the work was completed in 1971. Dredging from the channel and the impoundment basin followed until a severe nor'easter storm opened a breach on the northern side of the tidal shoal within the inlet in 1973. The breach was filled and closed with dredged materials in 1974, and maintenance dredging continued through 1977.

In 1977 dredged sediment was disposed offshore in an area approximately 2.4 km (1.5 mi) north of the inlet in -7.6 m (-25 ft) of water. As erosion continued along the northern beach, it also was proposed by the COE to place dredged materials directly on a 2,438-m (8,000-ft) section of beach beginning one mile north of the inlet. This overall beach nourishment and inlet stabilization program failed however, and these unexpected results can be summarized as follows: continuous, large-scale accretion occurred on the shoreline immediately south of the inlet; shoaling occurred within the inlet; and the navigation channel migrated northward cutting through the impoundment basin (Mehta & Jones, 1978). A comparison of aerial photographs taken in 1973 and 1979 shows that substantial accretion took place at and around the southern jetty.

In a 1983 report, the COE noted "severe erosion occurred along the 1.6 km (1 mi) reach of the shore north of the inlet" and large volumes of sediments had accreted on the southern shore and within "storage" areas of the inlet. These volumes amounted to 1,529,000 m^3 (2,000,000 yd^3) on shore and approximately 1,911,400 m^3 (2,500,000 yd^3), in the water. The COE concluded that these volumes surpassed the littoral drift estimates for the area, and "the theory was put forward that the offshore by-pass bar migrated westward under the influence of construction."

The COE (USACE JD, 1983) noted that the sand-bypass system had failed because of improper construction of the weir and it outlined plans for remediation. These included temporarily closing the weir (which was accomplished in 1984), hopper and pipeline dredging of material from the channel, the impoundment basin and the "storage" areas, selective disposal of dredged material to nourish the southern beaches, and, after re-configuration of the adjacent shore, reopening of the weir.

8.22 Inlet Effects

Although the weir at Ponce de Leon Inlet was closed in 1984, and dredging initiated, Dean and O'Brien reported (1987) the accretion of 1,758,000 m^3 (2,300,000 yd^3) of sediment at a location 1,372 meters (4,500 ft) south of the inlet, and the severe erosion 12.9 km (8 mi) further south of the inlet on Bethune Beach immediately adjacent to Canaveral National Seashore. It is possible that the erosion at Bethune Beach may move to Canaveral NS.

To mitigate the erosion at Bethune Beach, the COE proposed placement of dredged materials on downdrift (south) beaches. "Because of the predominately southerly direction of the littoral transport along the considered shores, material should not be deposited on the north beach except to correct erosion" (USACE JD, 1983). The COE recommended the sand be placed by pipeline dredge 1.6 km (1 mi) south of the inlet jetty. In 1985 the COE placed 689,000 m^3 (900,000 yd^3) of sediment at nearshore locations south of Ponce de Leon Inlet. However in 1989, 664,000 m^3 (869,000 yd^3) of sediment were placed on north beaches (USACE JD, 1990 unpublished dredge history for Ponce de Leon Inlet).

8.23 Summary and Recommendations

Ponce de Leon Inlet maintenance dredging has in the past caused erosion problems for downdrift beaches that may ultimately affect Canaveral NS.

1) All dredged materials must be kept within the littoral drift system. Equivalent quantities of dredged or impounded sediments should be bypassed to the south, as ultimately, deficits caused by Ponce de Leon maintenance will be manifested on the narrow Canaveral NS beaches.

2) Because of the fragile nature of the wilderness areas at Canaveral NS, GPS/GIS and resource management data base projects should be initiated immediately.

3) Careful attention must be paid to the placement of sand to avoid distribution effects of localized accretion and erosion. A continuous program of sand bypassing and placement of necessary materials directly upon eroded beaches is recommended for Ponce de Leon Inlet.

9.0 Gulf Islands National Seashore

9.1 General Introduction

Gulf Islands National Seashore was authorized by Congress on 8 January 1971 and in addition to several sites on the mainland, includes six barrier islands located along the northern coast of the Gulf of Mexico. There are two distinct island groups in the seashore that extend 240 km (150 mi) from east to west. To the east, Santa Rosa Island and Perdido Key hug the Florida coast and provide shelter to Santa Rosa Sound and Pensacola Bay (Fig. 14). To the west, 85 km (52.8 mi) from Perdido Key, past Dauphin Island, Alabama, (Dauphin Island is not part of the Gulf Islands NS), are Petit Bois Island, Horn Island, and East and West Ship Islands (Fig. 15). These undeveloped barrier islands are located approximately 12 km (7.5 mi) offshore and protect Mississippi Sound and the Mississippi mainland. Two of the four islands, Petit Bois and Horn Island, are designated as wilderness areas.

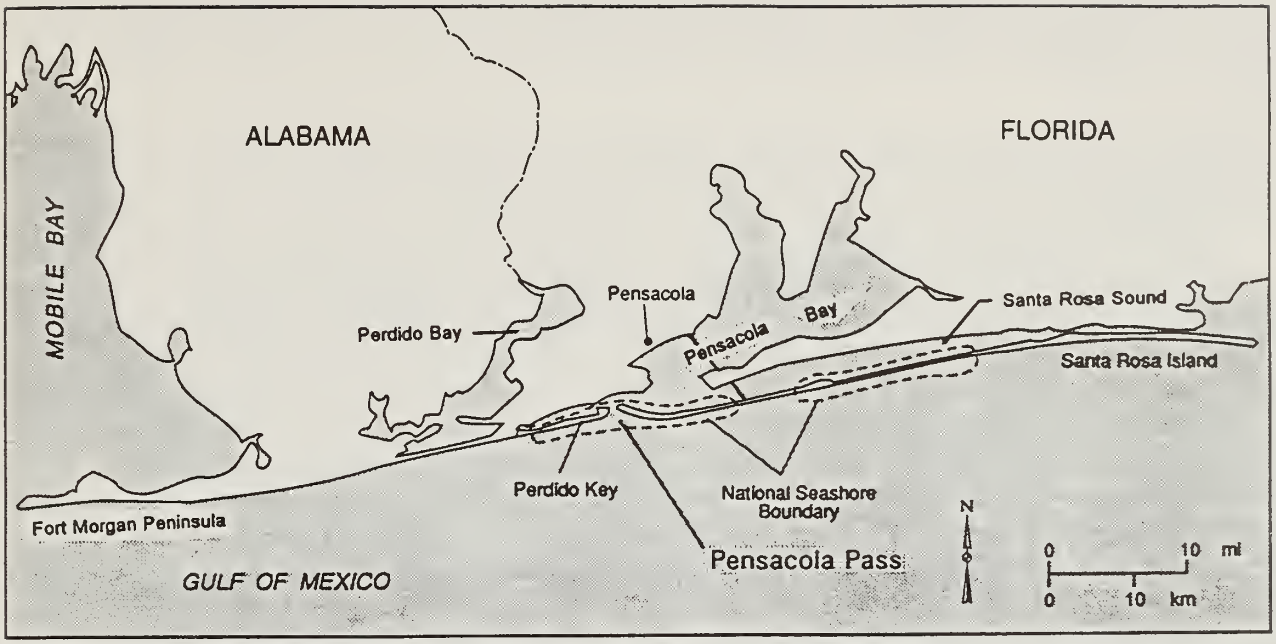

Fig. 14. East Islands: Perdido Key and Santa Rosa Island, Gulf Islands National Seashore, Florida.

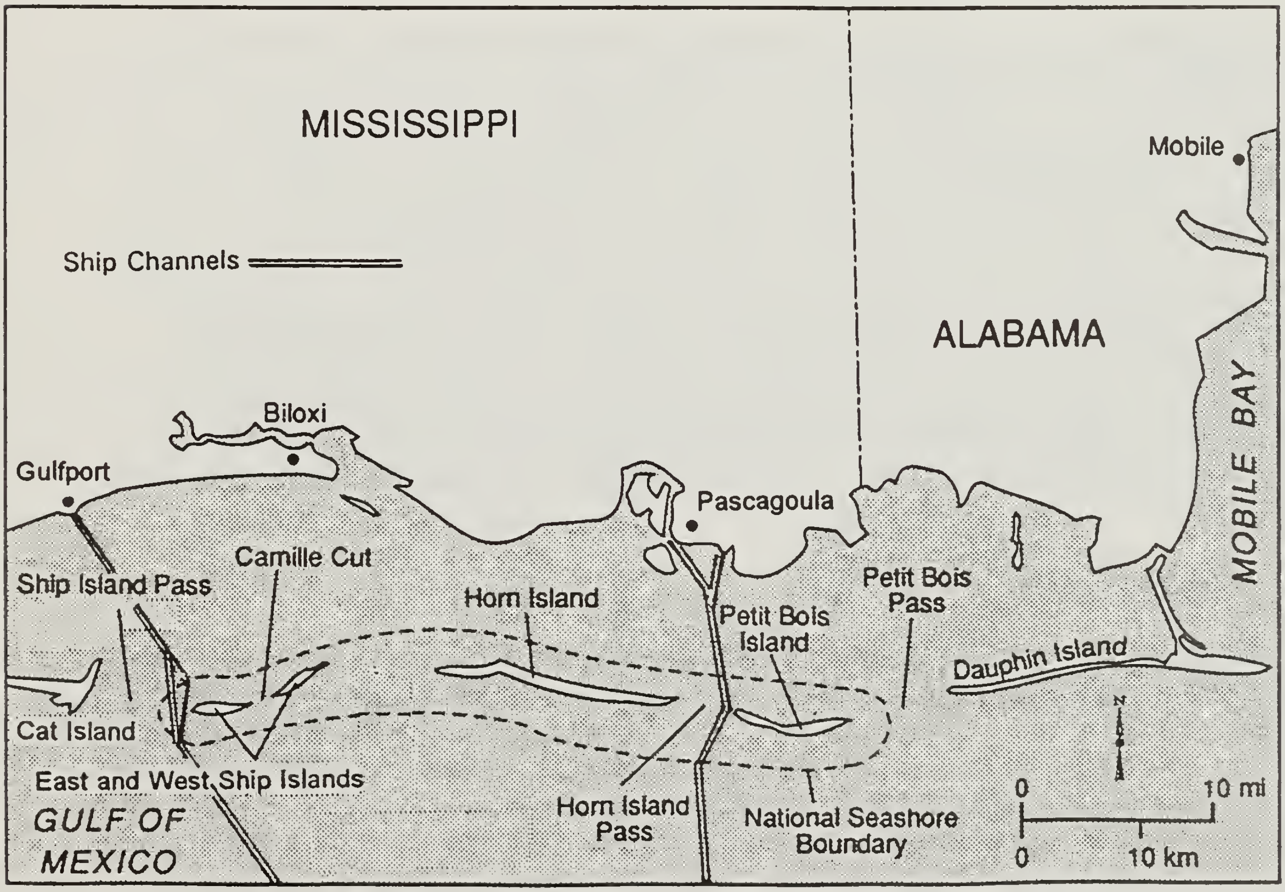

Fig. 15. West Islands: Petit Bois Island, Horn Island and East and West Ship Islands, Gulf Islands National Seashore, Mississippi.

Several units of Gulf Islands National Seashore are affected by channel maintenance. Pensacola Pass, between Perdido Key and Santa Rosa Island, has been extensively modified for military and commercial shipping. Two of the west gulf islands, Petit Bois Island and West Ship Island are migrating into federally maintained shipping channels. These will be discussed in the following sections.

9.2 Pensacola Pass

9.21 Introduction

The National Seashore in the Pensacola Bay area includes five sites. The Naval Air Museum is on the mainland and is unaffected by maintenance of Pensacola Pass. The Naval Live Oaks Area lies on a peninsula to the east of the inlet and is fronted by Pensacola Bay to the north and Santa Rosa Sound to the south. Naval Air Station Pensacola includes an active operational and training facility and the Navy home port at Pensacola serves as a vessel refit and training facility for large ships and aircraft carriers. Pensacola Pass is a natural inlet that lies between the NPS units at Santa Rosa Island and Perdido Key and is used by commercial, military, and recreational vessels. On Santa Rosa Island are two sections: the Santa Rosa day-use facility and the campground facilities. The campground area includes historic Fort Pickens, and lies on the western end of the island (Fig. 16). Across Pensacola Pass to the west, 11 km (6.8 mi) of Perdido Key complete the seashore area and provide additional daytime recreational facilities that are accessible by automobile, boat and walking.

Santa Rosa Island and Perdido Key are low relief sandy coastal barrier islands with dunes, marshes, ponds and wooded areas. According to Wicker et al. (1989), Santa Rosa Island can be characterized as a "transgressive barrier island shoreline," and Perdido Key as a "regressive barrier island shoreline," with dominant sediment transport to the west. The nearshore profile of Santa Rosa Island and Perdido Key is steep along the gulf shore, sloping 15.2 to 18.3 m/km (50 to 60 ft/mi) from the beach out to the inner continental shelf (Kwon, 1969). Kwon further reported that "Santa Rosa Island appears to be eroding in some sections, as suggested by exhumed peat from the beaches near the western end. In places dunes are presently being eroded." During the period from 1855 to 1934, the NPS gulf shore of Perdido Key receded landward from 91 m to 122 m (300 ft to 400 ft) [USACE JD, 1971]. In this report, the COE classified the eastern tip of Perdido Key as "having a critical erosion problem." Dean (1988) reported that "the net longshore transport in the vicinity of Pensacola Bay Entrance is from east to west with an estimated magnitude of approximately 200,000 m^3/yr (261,590 yd^3/y).

9.22 Inlet Modification

Pensacola Pass has been dredged for more than 100 years. Recently, in order to permit the use of the channel by the aircraft carrier USS Kittyhawk, the channel was widened and deepened with depths up to -14.6 m (-48 ft). "In its natural condition, depths over the ebb tidal shoal were on the order of -6 m (-20 ft) and formed a sand bridge from Santa Rosa Island to the downdrift Perdido Key" (Dean, 1988). However, because the channel bottom is now far below the natural bar depth, coastal processes act to fill the channel and restore the littoral-drift sand bridge, thereby resulting in a need for annual maintenance dredging to keep the channel at desired widths and depths.

According to the COE (USACE JD, 1990), the annual amount dredged from the channel between Santa Rosa Island and Perdido Key is approximately 612,000 m^3 (800,000 yd^3), and the dredging cycle restarts every two years. Dredging is typically accomplished with a hopper dredge and the materials are deposited in open water and along the seashore for beach renourishment.

Prior to 1985 dredged sediments were typically deposited approximately 5 km (3.1 mi) offshore and to the west of the navigation channel. Since 1985, dredged sediments are kept as a matter of practice within the littoral drift system. Reported quantities include approximately 840,000 m^3 (1,099,000 yd^3) in 1975, 500,000 m^3 (654,000 yd^3) in 1981, 87,000 m^3 (114,000 yd^3) in 1983, 443,000 m^3 (580,000 yd^3) deposited on Perdido Key in 1985 and 150,000 m^3 (196,000 yd^3) in 1987 (USACE JD, 1990).

9.23 Inlet Effects

Santa Rosa Island and Perdido Key have been and still are actively erosional. A review of aerial photos taken from 1945 to 1978 show erosion on the western end of Santa Rosa Island and erosion along the gulf coastline of Perdido Key. Following authorization of the seashore in 1971, during a 10-year period between 1974 and 1984, the Florida Department of Natural Resources collected shoreline change data for Perdido Key (Dean, 1988). According to Dean,

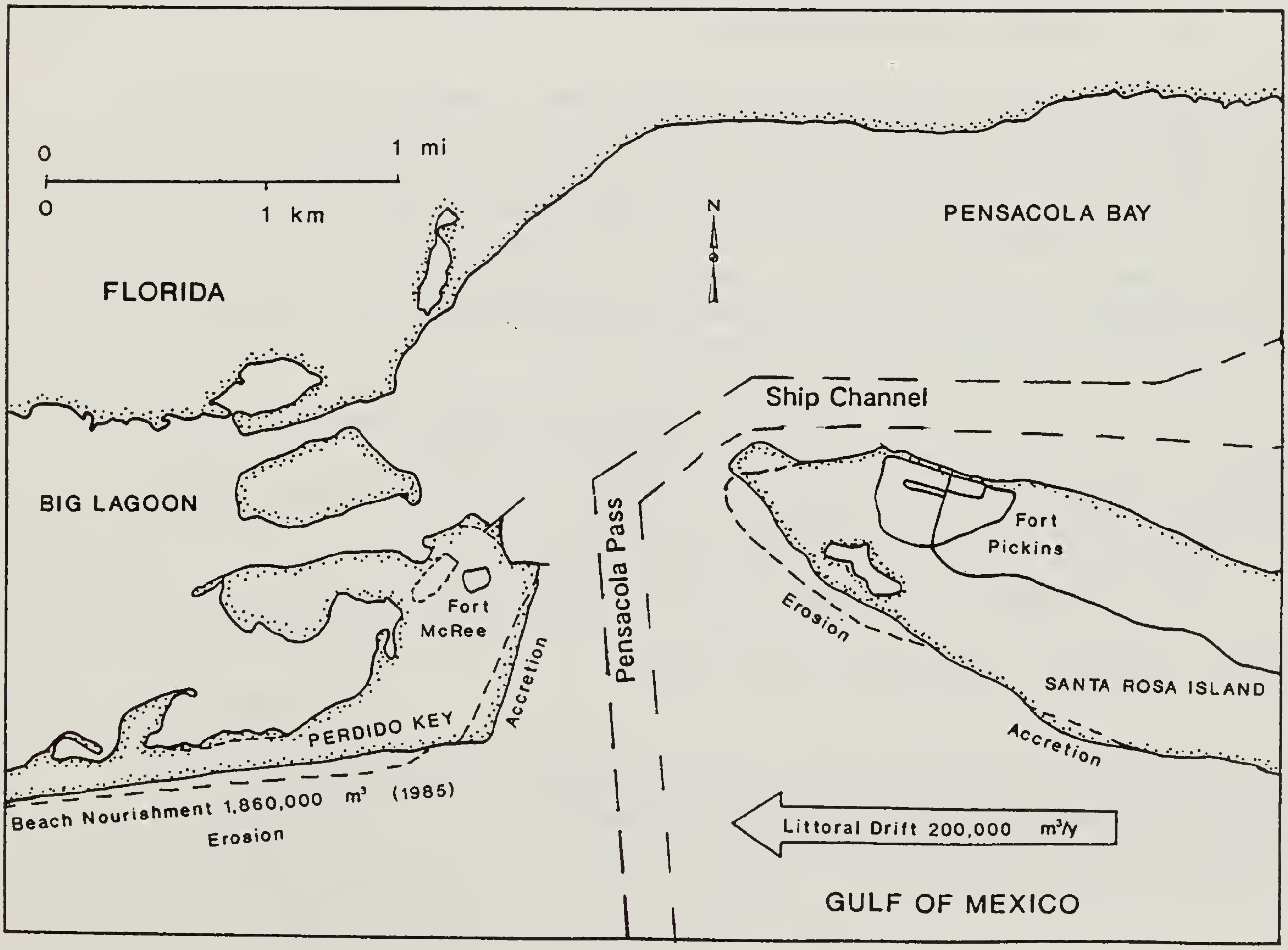

Fig. 16. Pensacola Pass, Gulf Islands National Seashore, Florida.

the data showed an average erosion rate of 1.3 m/y (4.3ft/y). The report stated that the shoreline rate-of-change translated to losses for the seashore of approximately 10 hectares (24.7 acres) of property each year. The report further stated that this erosion was caused by disposal at sea of sediments that were dredged from the channel at Pensacola Pass over its 100-year history, and specifically by recent deep channel dredging. According to Dean (1988), interruption of sediment transport of 200,000 m^3/y (262,000 yd^3/y) at Pensacola Pass results in the loss of approximately 100,000 m^3/y (131,000 yd^3/y) of sediment from the National Seashore section of Perdido Key.

In 1985, in order to reduce shore erosion, approximately 443,000 m^3 (580,000 yd^3) of sediment was placed by pipeline dredge on Perdido Key beach at the request of the NPS. Dean (1988) reported that the program was not completely successful because the materials were placed too high on the beach to allow for waves to contour the profile. A revised plan for beach nourishment and intensive monitoring was proposed whereby approximately 8,000,000 m^3 (10,465,000 yd^3) of sand would be placed on the eastern 5 km (3.1 mi) of Perdido Key, lower than the natural berm elevation on the beach and on the nearshore bottom to a distance offshore of about 335 m (1100 ft). This was expected to increase the beach width approximately 120 m (394 yd) over this region (Dean et al., 1990). Placement of 4,590,000 m^3 of dredged material on a 5 km section of the eastern end of Perdido Key and 2,600,000 m^3 in nearshore locations was completed in 1991.

9.24 Summary and Recommendations

Pensacola Pass maintenance dredging appears to have accelerated the natural gulf side recession of Perdido Key and Santa Rosa Island. The removal of sediment from the littoral-drift system, and its placement offshore in depths where it cannot re-enter the system cause "deficits" and increase erosional stress on adjacent shorelines. Placement of dredged sediments on Perdido Key beaches was initiated in 1985. Since 1985, as a matter of practice, the COE recommends dredged materials be placed on beaches or in the littoral zone as options preferable to offshore disposal. The following recommendations are made assuming the channel continues to be maintained at the present or larger configuration.

1) Rather than disposal at sea, materials dredged from nearshore locations should continue to be kept in the system and placed in nearshore locations or on beaches as needed. Proper placement of these sediments is an important issue that can be addressed through beach and bathymetric profiling.

2) In order to establish rates of shoreline and bathymetric change and distribution of dredged sediments, accurate mapping and a coordinated multi-agency monitoring program is necessary to establish a strong body of baseline data.

3) The creation of a seashore-specific resource management database will enable resource managers to establish baseline data sets and develop effective models and programs. This database will provide critical information to seashore administrators in the event of future modification to Pensacola Pass.

9.3 Horn Island Pass and West Ship Island Pass

9.31 Introduction

Until 1969, the western section of the Gulf Islands National Seashore comprised three Mississippi wilderness islands, Petit Bois, Horn, and Ship Islands (Fig. 15). Illustrating the highly sensitive and fragile nature of these narrow barrier islands, Hurricane Camille overwashed Ship Island in 1969 cutting it into East and West Ship Islands, thereby creating a broad new tidal channel (Camille Cut) between the two islands. Today, these islands are characterized like other barriers along the Gulf coast; low relief, sandy islands with scattered dunes, woodlands, interdune marshes and ponds. Except for NPS facilities and historic Fort Massachusetts on West Ship Island, the islands are uninhabited and support an extensive wildlife population including osprey, heron and blue and snow geese. The islands include some of the last remaining undisturbed plant communities in the northern Gulf of Mexico (Miller, 1975).

The Mississippi islands are unlike the Georgia and east coast Florida barriers in that the back-barrier areas do not have the well developed marshes seen for example at Cumberland Island, Georgia. Located approximately 12 km (7.5 mi) offshore, the Mississippi islands have historically undergone and continue to undergo dramatic change as gulf coast waves and currents rapidly erode the eastern ends and accrete sediments on the western tips. Kwon (1969) reported that the islands have remained at approximately the same distance from the mainland shore during the last several hundred years as they continue westward migration (Fig. 15).

The origin of the islands has been the subject of some debate. Hoyt (1967) suggested that barrier islands formed on land by wind or water accretion and were later drowned by rising sea level. Otvos (1979) hypothesized that the northern Gulf of Mexico islands appear to have formed by aggredation of offshore relict shoals whose original morphology was later obscured by island migration. In any case, the process of downdrift migration is dominant.

The source of sediment for Petit Bois, Horn and Ship Islands is the mainland coast of Alabama. According to Knowles et al., (1989) this sand is transported across the Mobile Bay ebb-tidal delta by the westerly littoral transport system, past Dauphin Island, supplying sand to the westward migrating barrier islands of the Gulf Islands NS.

Eighty kilometers (50 mi) updrift of Petit Bois Island, the net littoral transport rate at Perdido Pass, Alabama, was estimated at 153,000 m^3/y (200,000 yd^3/y) to the west (USACE MD, 1954). The COE (USACE MD,1989) estimated an annual littoral drift for Ship Island of 122,000 m^3/y (159,000 yd^3/y) to the west based on shoaling rates calculated from 1848 to 1947 at the west end of the island.

9.32 Inlet Modification

Of the four Mississippi barrier Islands, Petit Bois and West Ship Islands are of particular interest as they prograde into the dredged channels of Horn Island Pass (Pascagoula Ship Channel) and Ship Island Pass (Gulfport Ship Channel), respectively (Figs. 15, 17, 18). These islands are 10 km and 5 km long and are rapidly approaching extinction as they erode naturally on the eastern ends and are removed by dredging at their western ends.

Pascagoula Ship Channel lies immediately adjacent to Petit Bois Island, was first authorized in 1913 and is utilized by commercial, recreational, and military vessels entering and leaving the Port of Pascagoula, Mississippi. In 1976, the Port of Pascagoula was ranked 15th in the US in terms of port tonnage handled (Shabica, 1978). Maintaining the pass channel requires annual dredging averaging 229,000 m^3/y (300,00 yd^3/y) of sediment. The channel is maintained to a depth of -12.2 m (-40 ft) and a width of 106.7 m (350 ft) based on the Rivers and Harbors Act of 1962. The same act provided for a -12.2 m deep, 61 m wide and 457 m long (-40 ft, 200 ft, 1500 ft) impounding area constructed adjacent to the channel at the west end of Petit Bois Island. This impounding area serves as a catch basin for sand transported in the littoral drift system and reduces the amount of sand entering the channel. Sand in the impoundment area is periodically dredged using a pipeline dredge. The material removed from the impoundment area is usually disposed of on "Sand Island" or within the littoral zone south of Horn Island. Sand Island (unofficial name) is a dredged material disposal island created by the disposal of impoundment sand immediately to the west of the basin and the channel. Sediments dredged from the gulf portion of the channel have in the past been deposited south of Horn Island outside the littoral zone in water -9.1 m (-30 ft) to -12 m (-40 ft) deep (USACE MD, 1990). The sediments are now deposited in the littoral zone in water less than -6 m (-20 ft) deep.

Petit Bois Island has moved an average of 52.2 m/y (187 ft/y) to the west over the period from 1856 to 1977 (Shabica, 1978). The eastern tip of Petit Bois Island is also reported to have eroded 14 km (8.7 mi) since it's separation by severe storms from Dauphin Island in the late 18th century. Petit Bois' westward migration was halted in 1940 by the Pascagoula Ship Channel (Horn Island Pass).

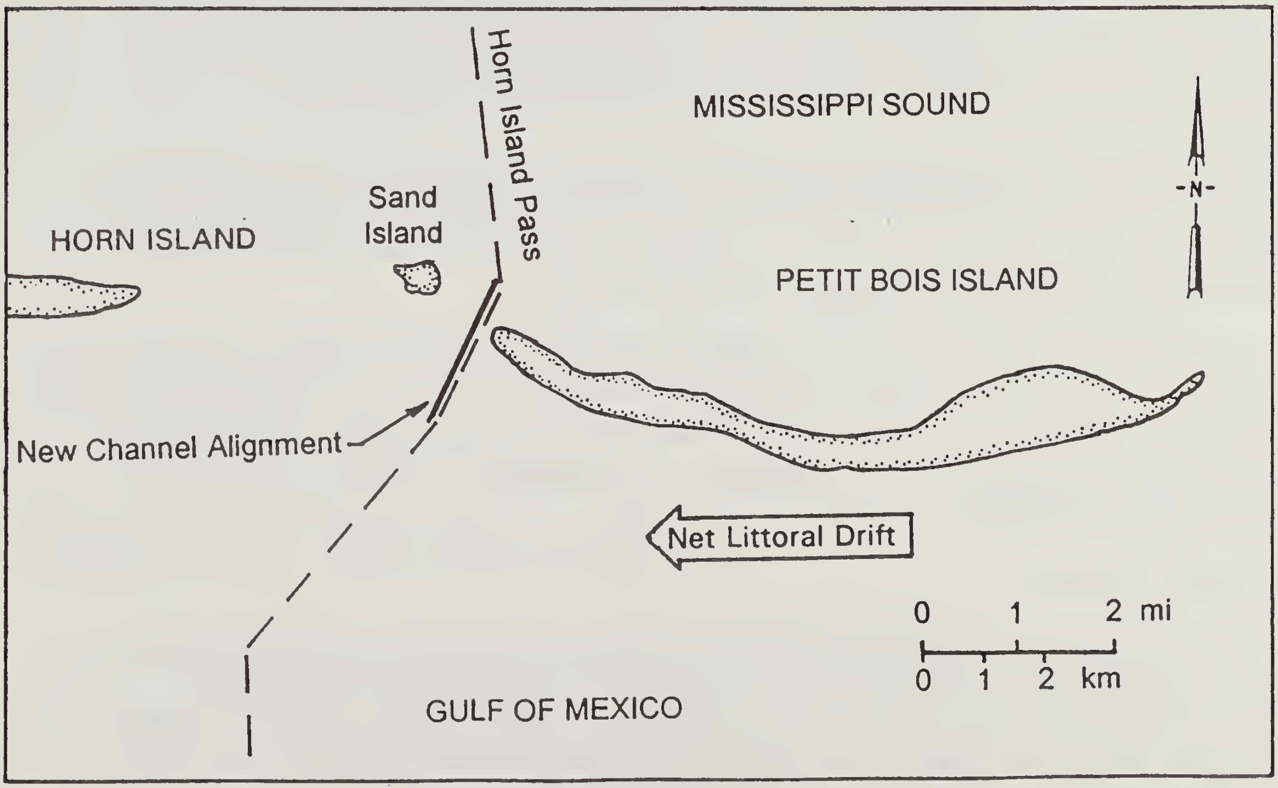

Fig. 17. Horn Island Pass and Petit Bois Island, Gulf Islands National Seashore, Mississippi.

Gulfport Ship Channel (Ship Island Pass), by comparison, is equally important as a commercial channel, serving the harbor of Gulfport Mississippi. Adjacent to Ship Island (Fig. 18), the channel was first authorized in 1899 and was authorized to its present configuration of -9.8 m (-32 ft) deep by 94.1 m (300 ft) wide in 1948 (USACE MD, 1990). In 1986, Congress authorized modification of the existing ship channel to -11.6 m (-38 ft) deep by 122 m (400 ft) wide. Realignment of the Ship Island Pass channel 305 m (1000 ft) west of the present channel and a -11.6 m (-38 ft) deep, 91.4 m (300 ft) wide by 610 m (2000 ft) long impoundment basin were also approved at a total project cost of $81,700,000 (USACE MD, 1990). The re-alignment project is due to be completed in August, 1993 (Susan Reese, Mobile District, USACE MD, personal communication, 1993).

Annual maintenance dredging of 382,277 m^3/y (500,000 yd^3/y) is required for the entire length of Gulfport Ship Channel (USACE MD, 1989). Of this, approximately 121,564 m^3 (159,000 yd^3) is dredged from the channel adjacent to the western end of West Ship Island. Most of the dredged sediments are dumped offshore in the Gulf of Mexico. In the past, based on requests by the NPS, some of this material was used to nourish beaches adjacent to Fort Massachusetts on the eroding northern shore of West Ship Island (USACE MD, 1990).

9.33 Inlet Effects

A comparison of aerial photos of the western tips of Petit Bois and West Ship Islands demonstrate a high rate of sediment accretion for the period from 1963 to 1982. Otvos (1979) reported that westward prograding Petit Bois and West Ship Islands "are spilling into their

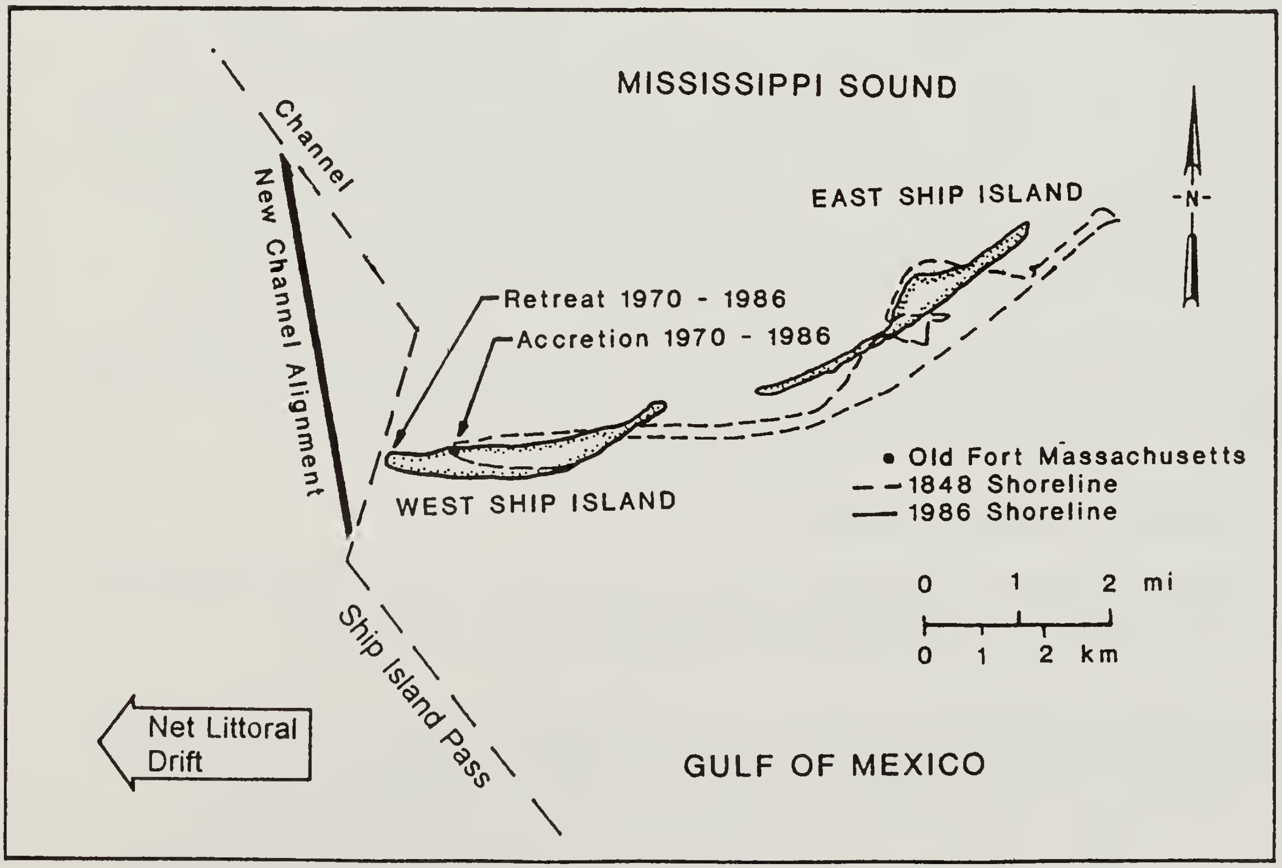

Fig. 18. Ship Island Pass and West Ship Island, Gulf Islands National Seashore, Mississippi.

respective tidal channels, and maintenance dredging is necessary to keep (the channels) open and stationary."

"Based on present channel maintenance requirements, approximately 2.8 to 4.1 hectares (7 to 10 acres) of the island (Petit Bois) are removed annually by maintenance operations. Materials dredged from the impoundment area and the associated channel are deposited northward of the channel, effectively removing this sediment from the littoral drift sediment transport system" (Shabica, 1978).

In 1989 the COE reported that the western tip of Ship Island had migrated westward by about 1,372 m (4,500 ft) since 1848. The dredging of Ship Island Pass has interfered with progradation of the western tip of the island, contributing to a significant loss of land area of the island. Volumetric change data indicate a steady decrease in the volume of sediments supplying the prograding western end of West Ship Island since 1848. During that same time interval, subaerial change to the island that were caused by erosion has been dramatic with a total land loss of approximately 263 hectares (650 acres) or about 43% of the 1848 land area (1.82 hectares/y [4.5 acres/y]).

Because the islands have been migrating so rapidly into the channels, channel relocation studies (USACE MD, 1990) have been completed for the Ship Island Pass (Gulfport Ship Channel). Plans include relocating the ship channel 579 m (1900 ft) to the west (downdrift) and are presently being implemented. Plans for dredge quantities are pending approval (Susan Reese, COE, Mobile District, personal communication, 1993) and call for dredging of a total of 11,090,000 m^3/y (14,500,000 yd^3/y) of material from the channel. Of this, 765,000 m^3/y (1,000,000 yd^3/y) will be thin-layered in Mississippi Sound, 2,000,000 m^3/y (2,600,000 yd^3/y) will be placed in the littoral zone near Cat Island and the rest will be taken to the Gulf of Mexico (USACE MD, 1990). Annual maintenance material from this project will total 587,000 m^3/y (768,000 yd^3/y). Of this, 229,000 m^3/y (300,000 yd^3/y) will be thin-layered in Mississippi Sound, 145,000 m^3/y (190,000 yd^3/y) will be placed in the littoral zone near Cat Island and the remaining 213,000 m^3/y (278,000 yd^3/y) will be taken to the Gulf of Mexico (USACE MD, 1990). As part of the project, the distribution of dredged material in "thin-layers" will be carried out as a demonstration test for possible "low-impact" on benthic community organisms. An earlier study completed in 1988, indicated that benthic communities recovered quickly (within 20 weeks) after being covered with a thin layer of dredged material (USACE MD, 1990, Appendix E). Plans also include periodic placement of dredged materials near Fort Massachusetts as needed to protect the fort from erosion.

9.34 Summary and Recommendations:

Petit Bois Island is migrating into the maintained Pascagoula Ship Channel. The result is a net loss of NPS land that would otherwise naturally accrete and be revegetated.

If dredging continues in the Horn Island Pass section of the Pascagoula Ship Channel, we estimate that in 75 years the western 4.5 km (2.8 mi) of Petit Bois Island including the wooded upland section will be entirely destroyed leaving an unforested topographically low barrier island 5.5 km (3.4 mi) in length. This calculation is based on an erosion rate of 60.1 m/y (Shabica et al., 1978). These authors recommended that Pascagoula Ship Channel be relocated to the east (updrift) of Petit Bois Island. A feasibility study for relocation of the ship channel

away from Petit Bois Island has been completed by the COE (Susan Reese, Mobile District, USACE MD, personal communication, 1993). Relocation was not considered feasible due to high costs and adverse environmental impacts.

At a rate of erosion of 11.58 m/y (38 ft/y), West Ship Island lost 1.82 hectares/y (4.5 acres/y) to dredging (USACE MD, 1989). Plans to relocate Gulfport Ship Channel (Ship Island Pass) 579 m (1900 ft) to the west (downdrift of West Ship Island) were approved and the project has been completed (Susan Reese, Mobile District, USACE MD, personal communication, 1993). According to the COE (USACE MD, 1989) this will allow 50 years before the island tip reaches the channel edge.

1) Relocation of the Pascagoula Ship Channels is critical to the continued environmental health of Petit Bois Island. We recommend that the COE feasibility study be reviewed by a multi-agency team to evaluate the study's conclusions that relocation is not feasible.

2) Because of the extremely fragile nature of the wilderness areas on Petit Bois and Ship Islands, GPS/GIS and resource management data base projects should be initiated immediately, bringing new COE mapping and management systems into the seashore-specific NPS RMDB.

3) Monitoring of the current dredging and channel-relocation programs should continue. Dredged materials should continue to be kept in the littoral-drift system or used to renourish eroding wilderness area beaches as needed.

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